Appendix N

International Border Region of the Colorado River

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Contents

Tables

Map

Figures

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

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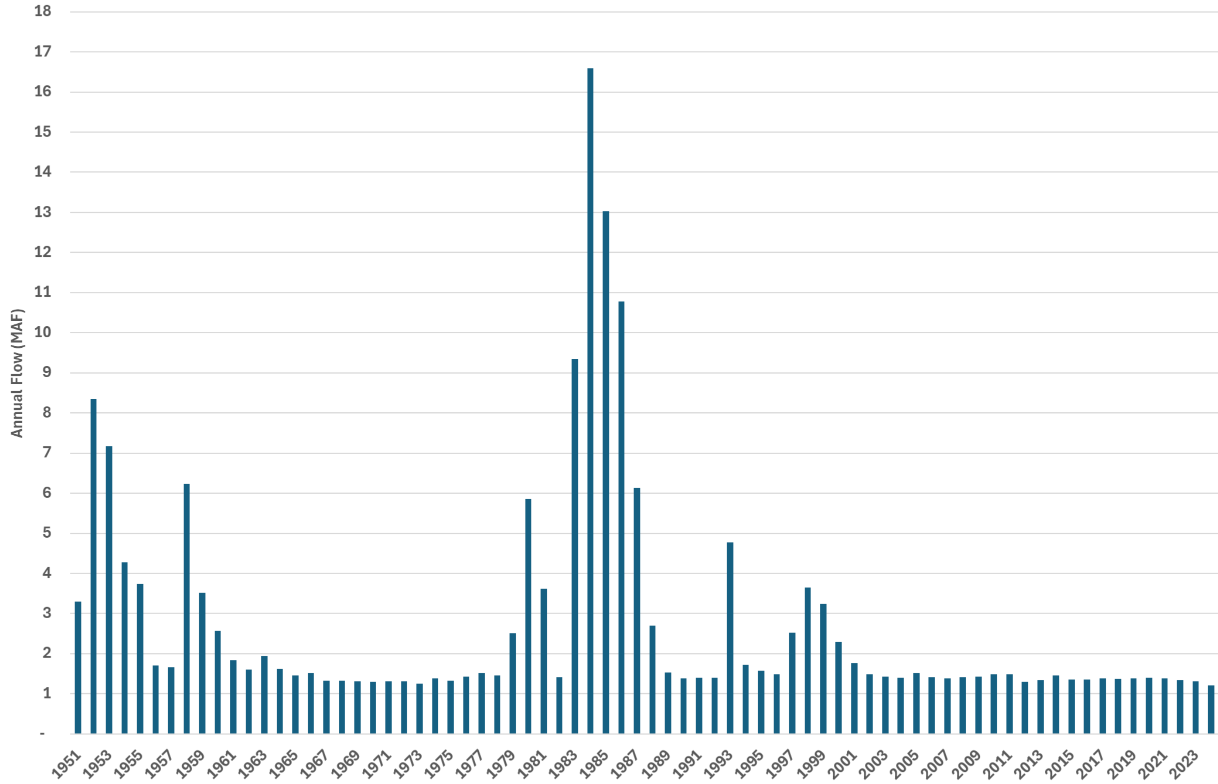
Map N-1 Colorado River Infrastructure and Hydrologic Features near the U.S. and Mexico Border

Figure N-1
Colorado River at Northerly International Boundary (NIB) Above Rockwood Weir



Source: IBWC 2026, USGS 2025a

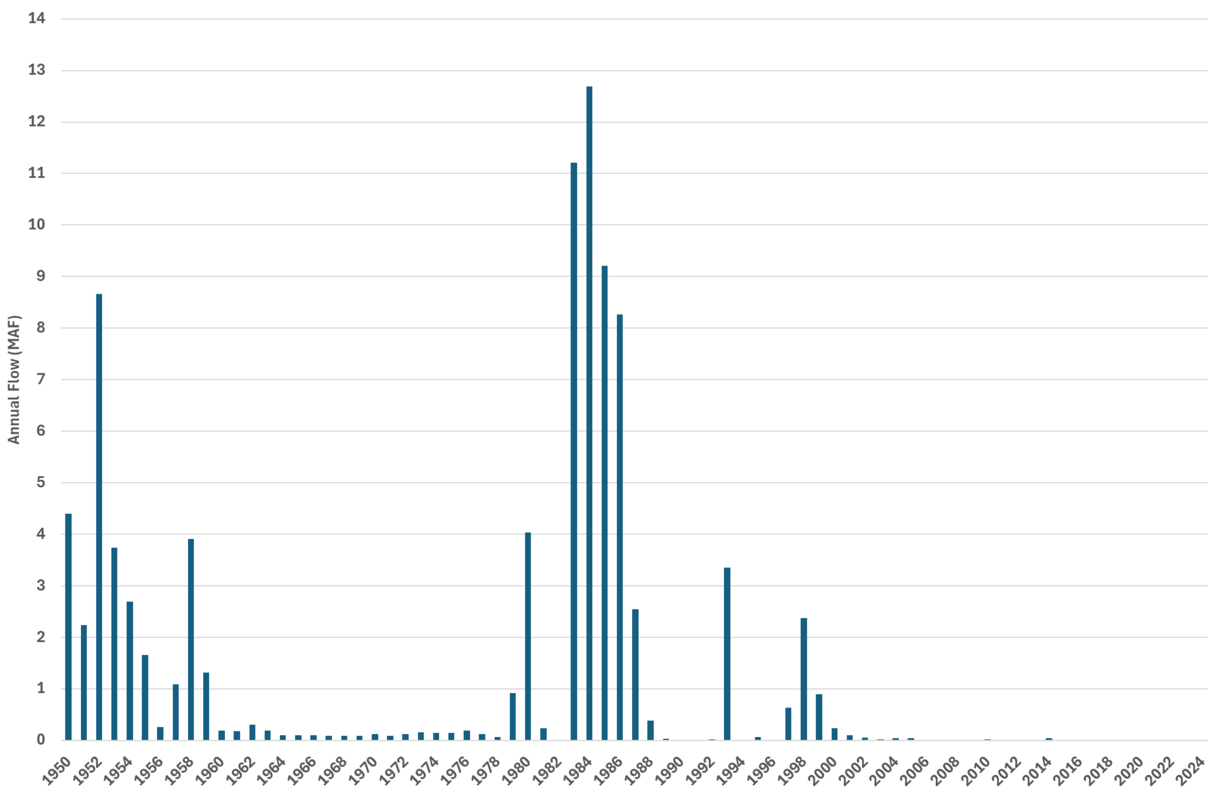
receives less than 3 inches of annual rainfall. Major flows in the Limitrophe have not regularly occurred since the 1980s and to a lesser degree in the 1990s when the reservoirs of Lake Powell Mead and Lake Mead were nearly full and spilling water was required. Notable events occurred from the 1993 Gila 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:

$$\begin{array}{c}\text{Mexico's annual}\\ \text{allotment}\\ \text{(1.5 maf)}\end{array} = \begin{array}{c}\text{Annual water delivery}\\ \text{to Mexico}\end{array} + \begin{array}{c}\text{Annual water delivery}\\ \text{reduction to Mexico}\end{array}$$

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

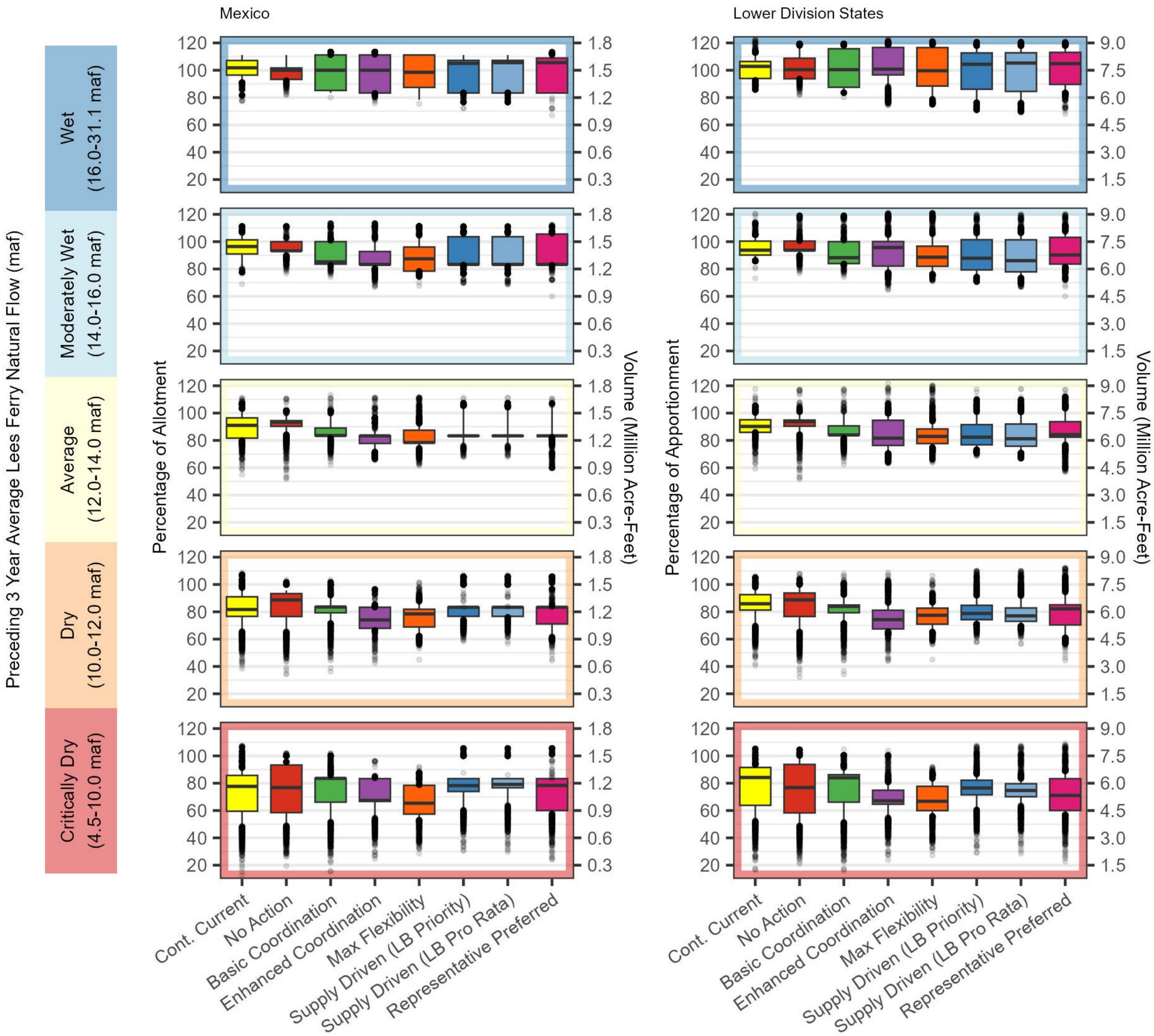
Water Deliveries to Mexico are described in **TA 4**, Water Deliveries, and summarized here. Water deliveries to Mexico are a function of assumed reductions to Mexico and assumptions about the deferral and delivery of conserved water to Mexico. Reclamation's modeling assumptions are not intended to constitute 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

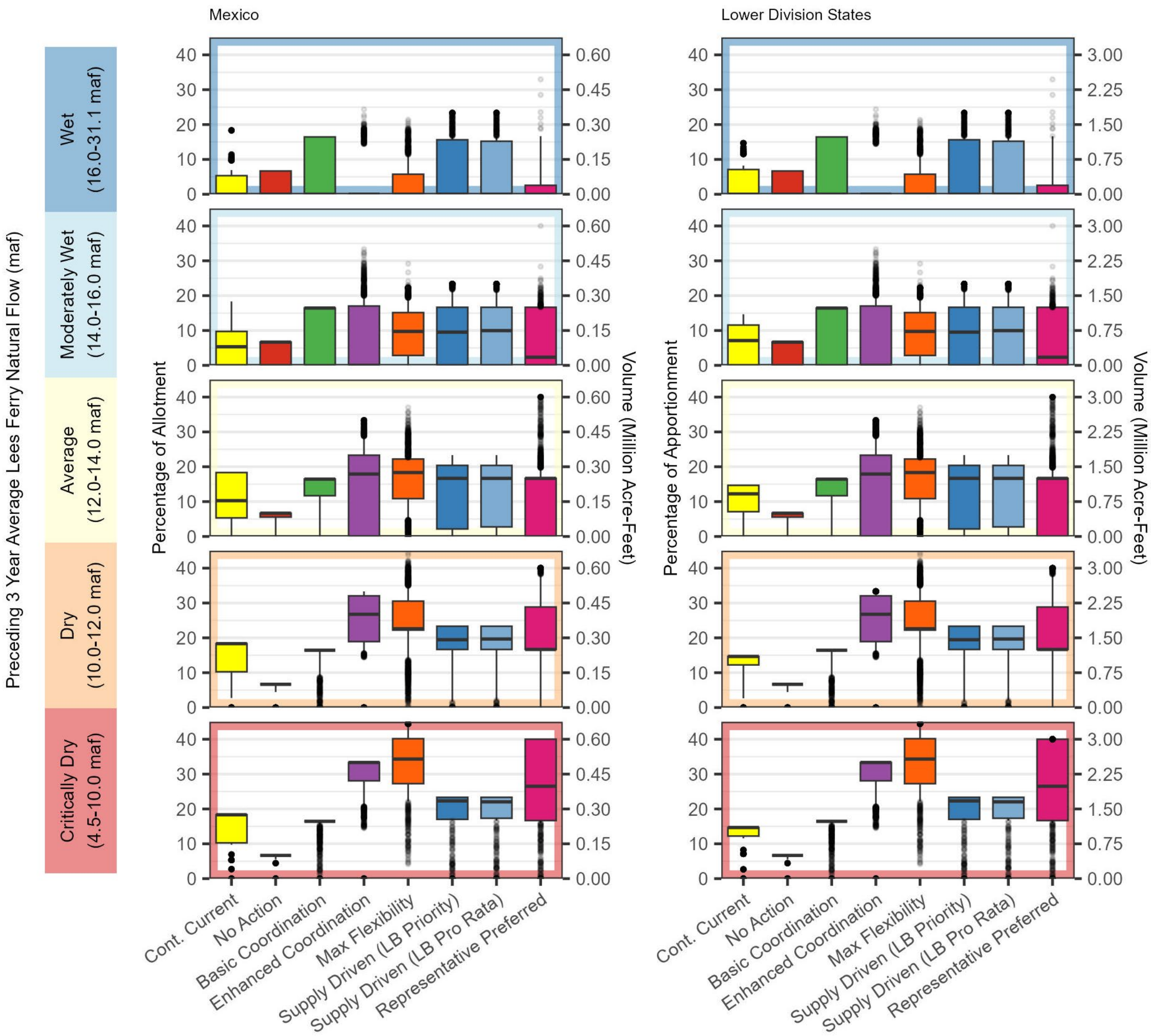
Note: The modeled annual depletions in Mexico include modeling assumptions for reductions in water deliveries to Mexico and deferred deliveries that are available to Mexico for future delivery. Reclamation's modeling assumptions are not intended to constitute an interpretation or application of the 1944 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.

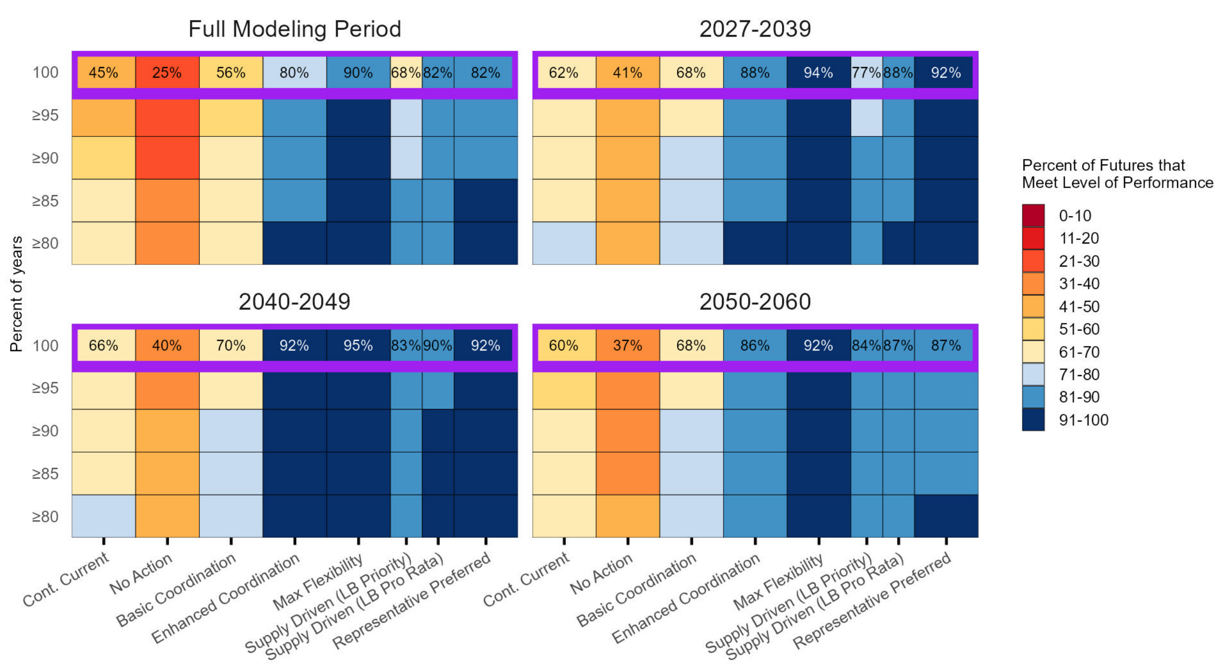
The cell values in **Table N-5** demonstrate how the magnitude of potential planned water delivery reductions generally increases based on the maximum reduction designed within the alternative, allowing a relative ranking of the alternatives from the lowest reductions in the No Action Alternative and 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

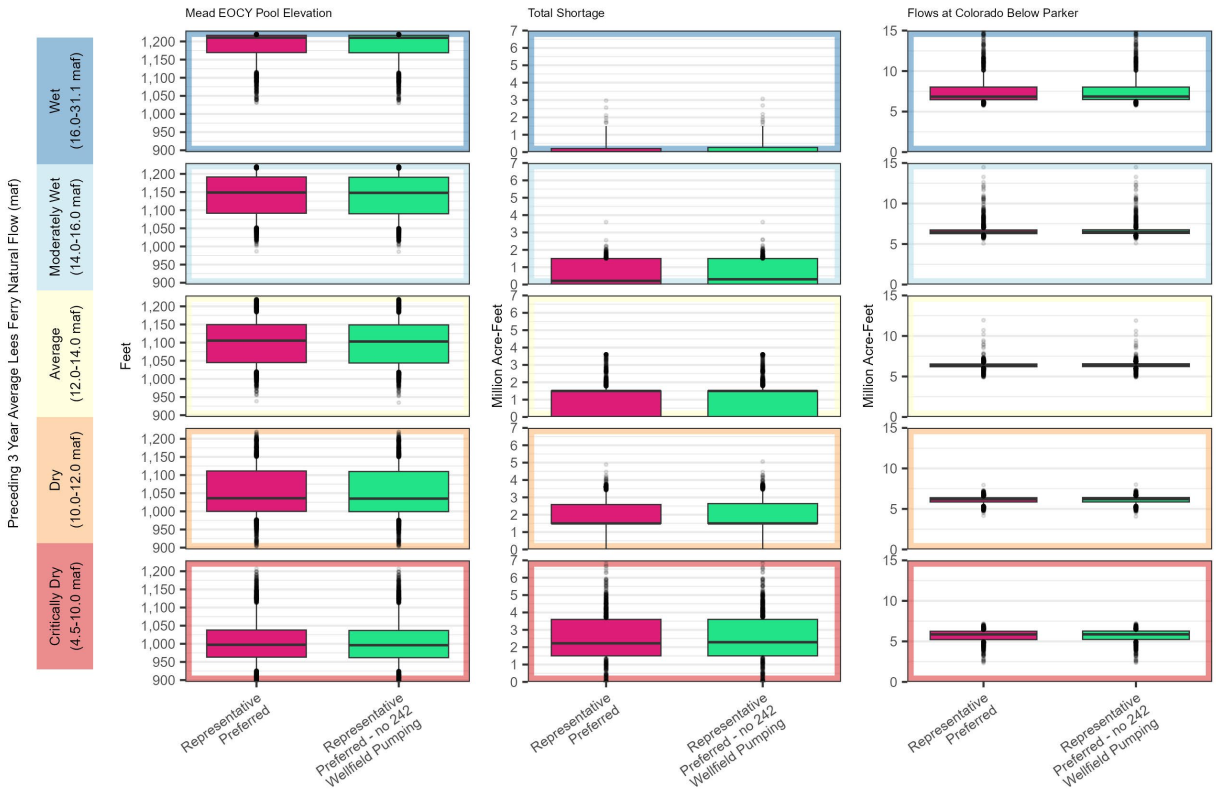
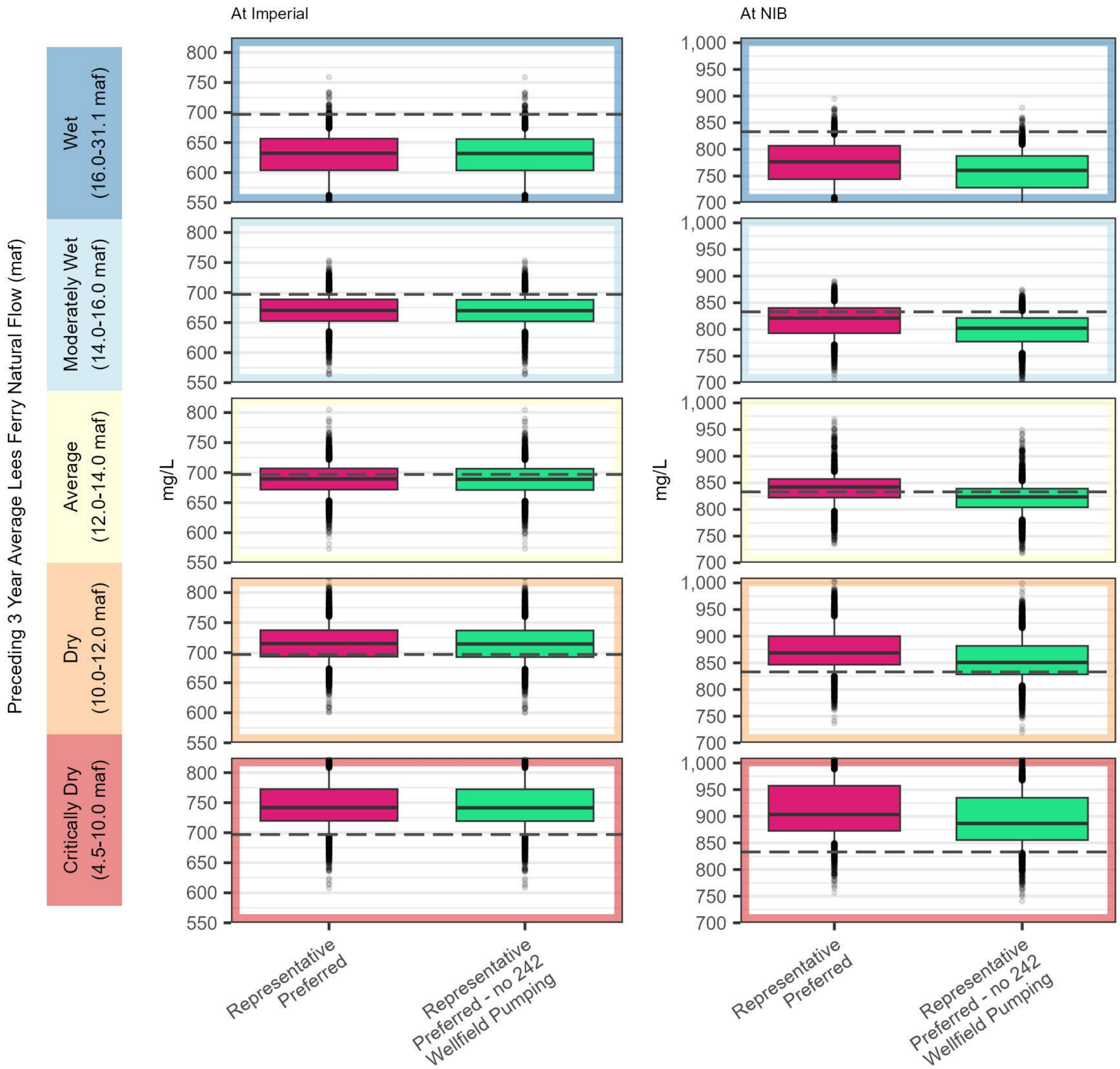


Figure N-7
Implications on Annual Flow-Weighted Average Salinity Concentrations when Removing Pumped Groundwater Contributions



N.4.2.1 Salinity ranges at Imperial Dam and NIB

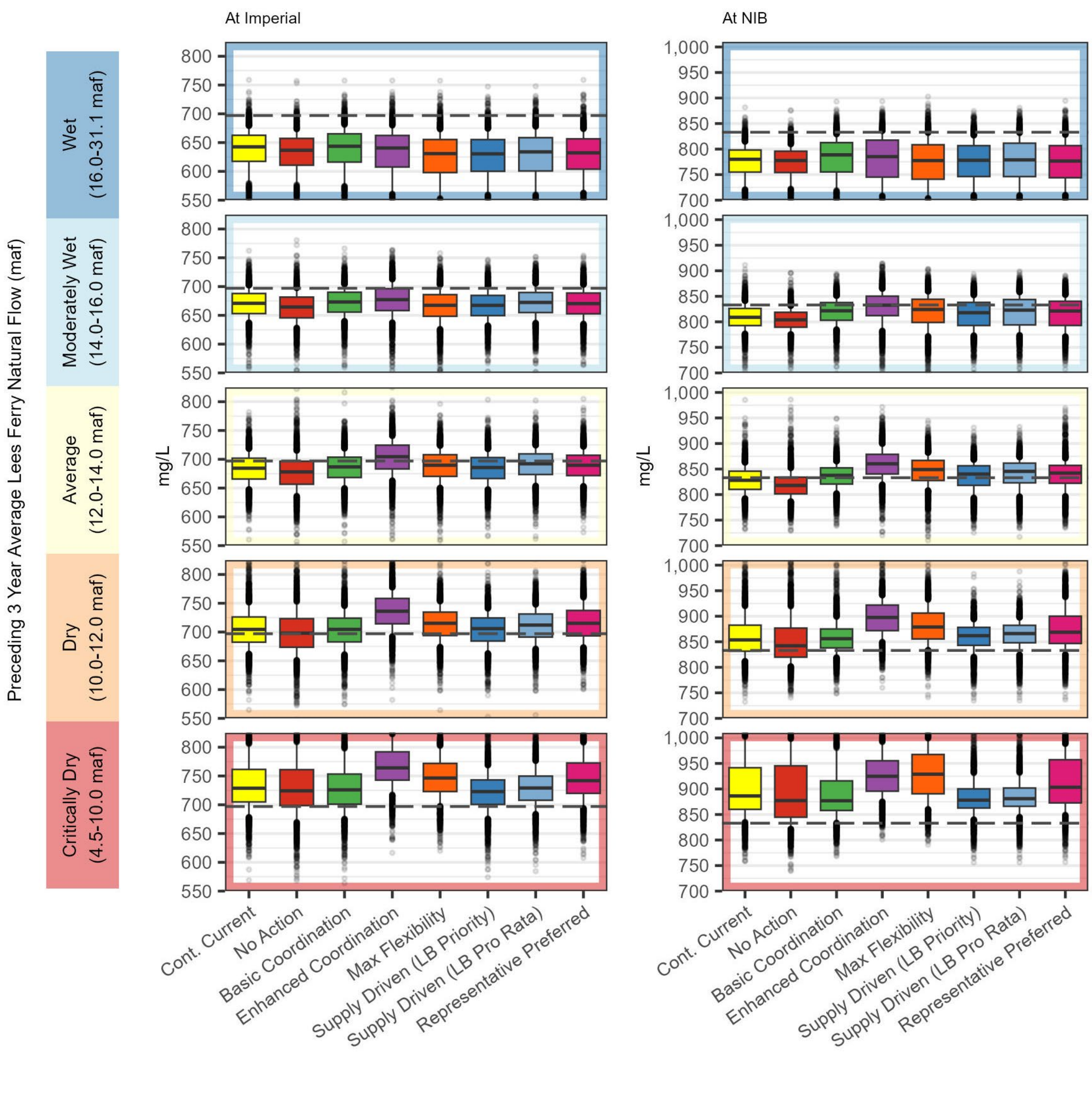
Average annual salinity ranges at Imperial Dam and NIB for the modeled alternatives are shown in **Figure N-8** using the same 5 preceding hydrologic flow categories to help visualize the different relative impacts throughout the 34-year period of analysis. While these graphics suggest similar impacts 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.

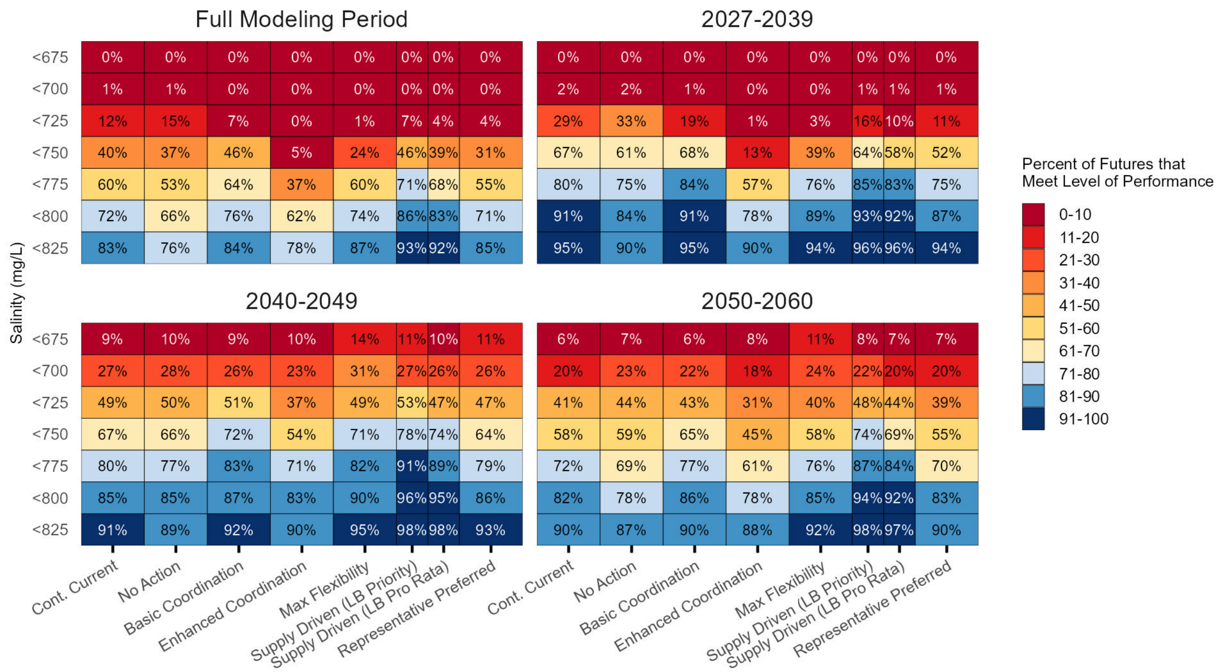
N.4.2.2 Number of traces that average annual salinity at Imperial Dam and NIB exceed tolerances[5]

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.

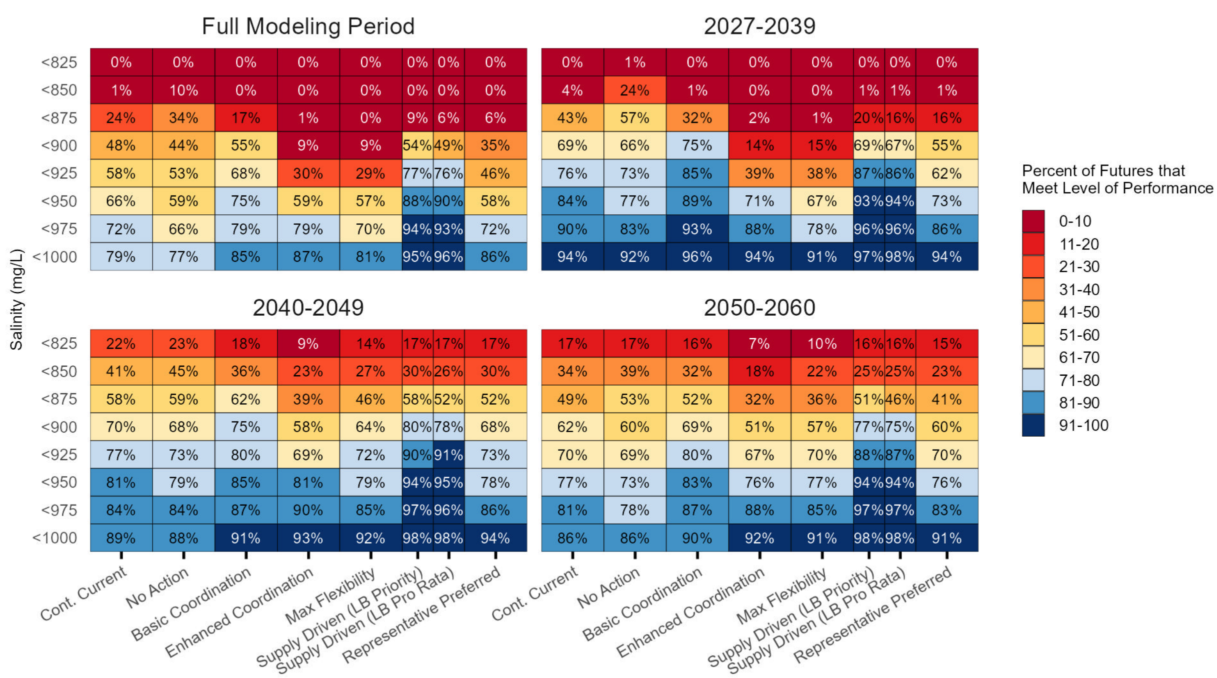
Figure N-9
Salinity at Imperial: Robustness
Percent of futures in which the concentration is below the specified value in every year



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

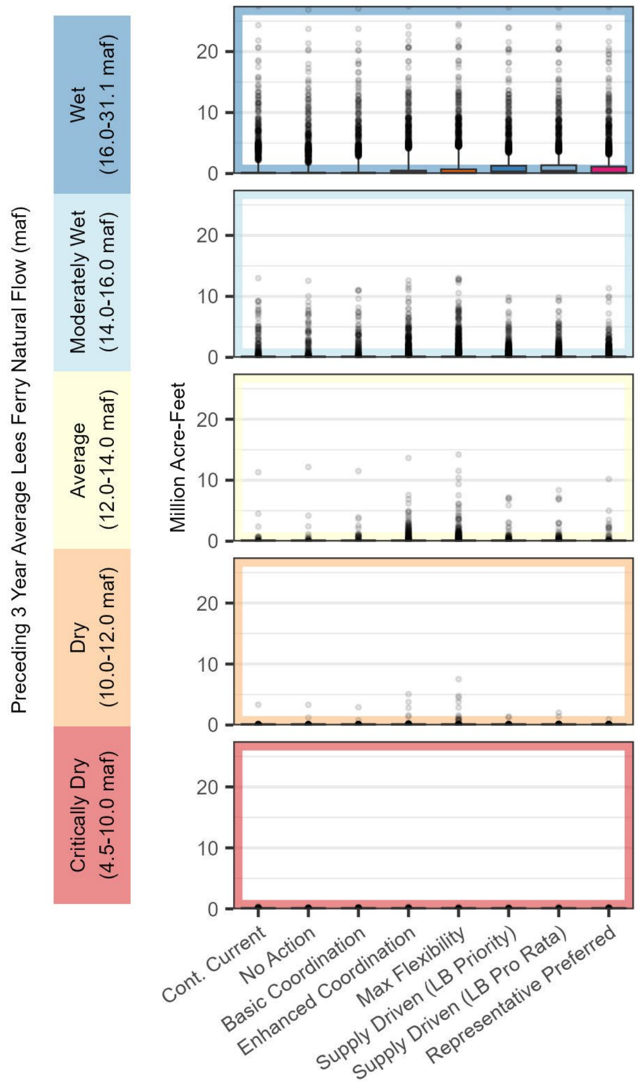
As shown previously in **Figure N-2**, flows in the Limitrophe were historically significant in the 1980s during flood control years; however, in recent years these flows have been limited to water passing Morelos Dam in excess of Mexico's scheduled delivery due to flood control operations at Hoover 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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