

Appendix 1
Plan of Study

Appendix 1 — Plan of Study

Note: This document was originally published with two attachments which are not included in this appendix.

1.0 Introduction

The Bureau of Reclamation's Upper Colorado and Lower Colorado Regions (UC and LC Regions), in collaboration with representatives of the seven Colorado River Basin States (Basin States¹), submitted a proposal in June 2009 to fund the Colorado River Basin Water Supply and Demand Study (Study) under the Basin Study Program (Program). In September 2009, the Study was selected for funding under the Program. The estimated total cost of the Study is \$2 million, with an equal cost-share of 50 percent by Reclamation and 50 percent by agencies in the Basin States (the non-Federal Cost-Share Partners). The Study will be conducted over a period of two years, beginning in January 2010.

This Plan of Study contains: the Study's purpose and objectives; a description of the Study management structure; a description of the major phases of the Study and a breakdown of the major tasks in each phase; a plan for public involvement throughout the Study (Attachment 1); and the June 2009 proposal (Attachment 2).

1.1 Study Purpose & Objectives

The purpose of the Study is to conduct a comprehensive study to define current and future imbalances in water supply and demand in the Colorado River Basin (Basin) and the adjacent areas of the Basin States that receive Colorado River water for approximately the next 50 years, and to develop and analyze adaptation and mitigation strategies to resolve those imbalances.

The Study will characterize current and future water supply and demand imbalances in the Basin and assess the risks to Basin resources. Resources include water allocations and deliveries consistent with the apportionments under the Law of the River²; hydroelectric power generation; recreation; fish, wildlife, and their habitats (including candidate, threatened, and endangered species); water quality including salinity; flow and water dependent ecological systems; and flood control. Specific objectives of the Study include:

- Characterization of the current water supply and demand imbalances in the Basin including the assessment of the risks to Basin resources from historical climate variability.
- Characterization of future water supply and demand imbalances under varying water supply and demand conditions in the Basin including the assessment of the risks to Basin resources from possible future impacts of climate change.

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

² The treaties, compacts, decrees, statutes, regulations, contracts and other legal documents and agreements applicable to the allocation, appropriation, development, exportation and management of the waters of the Colorado River Basin are often referred to as the Law of the River. There is no single, universally agreed upon definition of the Law of the River, but it is useful as a shorthand reference to describe this longstanding and complex body of legal agreements governing the Colorado River.

- Identification of potential strategies and options to resolve Basin-wide water supply and demand imbalances including:
 - Modifications to the operating guidelines or procedures of water supply systems;
 - Modifications to existing facilities and development of new facilities;
 - Modifications to existing water conservation and management programs and development of new programs;
 - Modifications to existing water supply enhancement programs and development of new programs; and
 - Other structural and non-structural solutions.
- Identification of potential legal and regulatory constraints and analysis of potential impacts to water users and Basin resources for the strategies and options considered.
- Prioritization of identified strategies and options and the recommendation for potential future actions, including feasibility studies, Congressional authorization, environmental compliance activities, demonstration programs, and/or implementation as appropriate.

1.2 Study Management

Management of the Study by the UC and LC Regions and the non-Federal Cost-Share Partners will be accomplished as described in the following sections.

1.2.1 Co-Study Managers

One Co-Study Manager will be designated from Reclamation and one Co-Study Manager will be designated from the Non-Federal Cost Share Partners. The Co-Study Managers will sit on and lead the Steering Team.

1.2.2 Steering Team

The Steering Team will steer and guide the efforts of the Project Team such that the objectives of the Study are met in an effective, efficient manner, and within the Study's financial and time constraints. The Steering Team will be comprised of one member from the UC Region, one member from the LC Region, one member from each Basin State, and one member from the Upper Colorado River Commission, for a total of 10 members.

1.2.3 Project Team

The Project Team will ensure that the tasks that relate to the Study are completed in a cost-effective, timely manner and are technically sound. Members of the Project Team provide the expertise, experience, and knowledge that relate to the Study's scope and objectives. Members include staff from the UC and LC Regions, staff from the non-Federal Cost-Share Partners, and staff from other entities who may be contracted to provide specific information, knowledge, and support. The Co-Study Managers will lead the Project Team.

1.2.4 Sub-Teams

Various Sub-Teams will be formed as needed to perform specific tasks. Sub-Team members provide specific expertise required to perform those tasks. Members are comprised of Project

Team members, additional staff from the UC and LC Regions and the non-Federal Cost-Share Partners, and staff from contracted entities. Membership may also include representatives from other groups with a particular expertise sought by the Sub-Team.

1.2.5 Reclamation Management Structure

To facilitate Reclamation’s oversight responsibilities and internal coordination, the proposed Study management structure includes a Reclamation Oversight Team (Oversight Team) and a Reclamation Study Team (Study Team). The Oversight Team provides oversight for the Study and will guide the efforts of the Study Team to ensure that the objectives of the Study are met within the financial and time constraints. Members of the Oversight Team are the Regional Directors of the UC and LC Regions and a senior member of the Office of Policy and Administration in Denver. Members of the Study Team include key staff from the UC and LC Regions.

1.3 Study Schedule, Phases, & Products

The Study will be technically oriented, incorporating information from the latest science, engineering technology, climate models, and innovations. The level of analysis of the strategies and options will be similar to an appraisal-level study to assist in justifying and preparing feasibility studies, Congressional authorization, environmental compliance activities, demonstration programs, and/or implementation as appropriate.

1.3.1 Schedule

The Study will be conducted over a period of two years, beginning in January 2010. The Study will consist of four major phases: Water Supply Assessment, Water Demand Assessment, System Reliability Analysis, and Development and Evaluation of Opportunities for Balancing Supply and Demand. The projected timeline for these phases is provided in figure 1. The projected Study milestones are listed in table 1.

FIGURE 1
Projected Study Timeline

Phase Name	1st Half 2010					2nd Half 2010					1st Half 2011					2nd Half 2011							
	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N
1. Water Supply Assessment																							
2. Water Demand Assessment																							
3. System Reliability Analysis																							
4. Development & Evaluation of Opportunities for Balancing Supply & Demand																							

TABLE 1
Projected Study Milestones

Milestone	Deliverable Description
September 2010	Report describing findings from current and future water supply assessment
September 2010	Report describing findings from current and future water demand assessment
April 2011	Report describing findings from system reliability analysis
August 2011	Report describing findings of opportunities analysis
October 2011	Draft Study report and appendices available for review
December 2011	Final Study report and appendices complete

Development and review of the draft and final Study report will follow the completion of the fourth milestone as shown above.

1.3.2 Phases

Table 2 provides the tasks and sub-tasks associated with the major Study phases.

TABLE 2
Overview of Study Phases

Phase 1. Water Supply Assessment. Assess the quantity and location of current and future water supplies throughout the Basin, including the potential effects of climate variability and climate change. Major tasks and sub-tasks include:	
1.1	Review & Select Methods to Estimate Current Supply
1.1.1	Historic Observed Record
1.1.2	Paleo Record
1.2	Review & Select Methods to Project Future Supply
1.3	Conduct Assessment of Current Supply
1.4	Conduct Assessment of Future Supply
1.5	Enhance Modeling Capability as Needed to Incorporate Methods to Project Future Supply
1.6	Conduct Sensitivity Analysis of Selected Methods to Project Future Supply
1.7	Prepare Draft Interim Report
1.8	Peer Review Report
1.9	Prepare & Publish Interim Report

TABLE 2
Overview of Study Phases

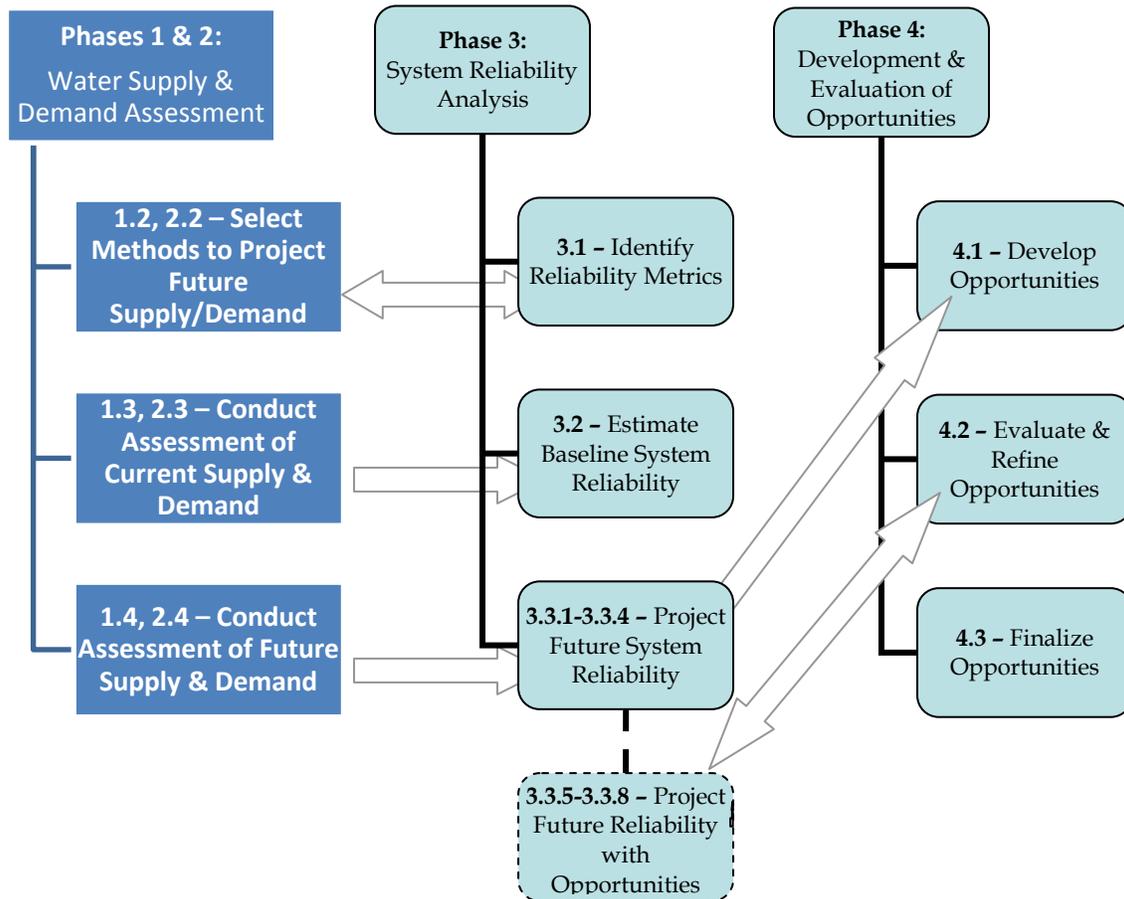
<p>Phase 2. Water Demand Assessment. Assess the quantity and location of current and future water demands, including the potential effects of climate variability and climate change. Major tasks and sub-tasks include:</p>	
2.1	Review & Select Methods to Estimate Current Demands
2.2	Review & Select Methods to Project Future Demands
2.3	Conduct Assessment of Current Demands
2.4	Assessment of Future Demands
2.4.1	Update State Demand Projections
2.4.2	Analyze Temperature Effects on Projected Use
2.5	Enhance Modeling Capability to Better Represent Future Demands
2.5.1	Reservoir Evaporation
2.6	Prepare Draft Interim Report
2.7	Peer Review Report
2.8	Prepare & Publish Interim Report
<p>Phase 3. System Reliability Analysis. Assess the capability of existing and proposed infrastructure and operations to meet future demands and water supply challenges. This analysis will include an assessment of the operational risk and reliability of the system currently and in the future. System reliability will be determined by describing the quantity and locations of supply/demand imbalances currently and in the future. Scenarios for baseline and future water supply and demand will be determined in Phases 1 and 2. Evaluate effectiveness of opportunities identified in Phase 4 in resolving imbalances. Major tasks and sub-tasks include:</p>	
3.1	Identify Model & System Reliability Metrics
3.2	Determine Baseline System Reliability
3.2.1	Determine Baseline Scenario Modeling Assumptions
3.2.2	Prepare Model to Simulate Baseline Scenario
3.2.3	Perform Model Simulations
3.2.4	Synthesize & Analyze Model Results
3.2.5	Summarize Model Results
3.3	Project Future System Reliability
3.3.1	Determine Future Scenario Modeling Assumptions
3.3.2	Prepare Model to Simulate Future Scenarios
3.3.3	Perform Model Simulations
3.3.4	Synthesize & Analyze Model Results
3.3.5	Determine Modeling Assumptions for Supply/Demand Opportunities
3.3.6	Prepare Model to Simulate Future Conditions Under Supply/Demand Opportunities
3.3.7	Perform Model Simulations with Supply/Demand Opportunities
3.3.8	Synthesize & Analyze Model Results
3.4	Prepare Draft Interim Report
3.5	Peer Review Report
3.6	Prepare & Publish Interim Report

TABLE 2
Overview of Study Phases

<p>Phase 4. Development & Evaluation of Opportunities for Balancing Supply & Demand. Identify and quantify potential opportunities to address imbalances in supply and demand in order to best meet future challenges. This analysis will include the identification and development of both structural and non-structural opportunities. As opportunities are refined, an iterative modeling process will be used to determine future system reliability under conditions where selected opportunities are assumed to be developed and/or implemented. Opportunities include but are not limited to: operational changes, legal and institutional changes, water conservation and efficiency, land fallowing and retirement, conjunctive use, upgrades, rehabilitation or replacement of existing facilities, water recycling and reuse, desalination, development of new conveyance and storage facilities, weather modification, vegetation management, dust abatement efforts, groundwater remediation, urban runoff management, and importation projects. Major tasks and sub-tasks include:</p>	
4.1	Develop Opportunities
4.1.1	Identify Opportunities
4.1.2	Determine Preliminary Opportunities for Evaluation
4.1.3	Analyze Opportunities (Preliminary)
4.2	Evaluate & Refine Opportunities
4.2.1	Technical Feasibility
4.2.2	Uniform Cost Comparison
4.2.3	Environmental Impacts/Permitting Requirements
4.2.4	Economic and Socioeconomic Impacts
4.2.5	Legal and Public Policy Considerations
4.2.6	Risk and Uncertainty
4.2.7	Others
4.2.8	Assessment of Effectiveness
4.2.9	Potential Yield
4.2.10	Timeframe for Implementation
4.2.11	Agreements or Partnerships Needed
4.2.12	Cost Allocation
4.2.13	Siting
4.3	Finalize Opportunities
4.3.1	Determine Ability of Opportunities to Resolve Imbalances
4.4	Prepare Draft Interim Report
4.5	Peer Review Report
4.6	Prepare & Publish Interim Report

Figure 2 illustrates the information transfer and coordination of tasks in the four major phases of the Study.

FIGURE 2
Flowchart of Major Study Phases



The first coordination occurs between Phases 1 and 2 and Phase 3 where the identification of the system reliability metrics in Task 3.1, in terms of spatial and temporal scale, depend upon the methods selected to project future supply and demand in Task 1.2 and Task 2.2. Baseline and future system reliability in Task 3.2 and Task 3.3, respectively, is determined based on the results of the assessment of current and future water supply and demand conditions in Task 1.3 (and Task 2.3) and Task 1.4 (and Task 2.4).

In Task 4.1, opportunities to resolve supply/demand imbalance will be identified considering the results of the projections of future system reliability in Tasks 3.3.1-3.3.4. The evaluation and refinement of those opportunities in Task 4.2 will be accomplished through re-projecting future system reliability under the identified opportunities in Tasks 3.3.5-3.3.8. After several iterations consisting of refining opportunities and projecting system reliability to determine the opportunities' performance, opportunities will be finalized in Task 4.3.

1.3.3 Products

The primary products of the Study will be interim written reports to be integrated into a final report that will include the following elements:

- Assessment of quantity and location of existing and future water supplies and demands throughout the Basin, including the potential effects of climate variability and climate change,
- Assessment of efforts currently being undertaken to reduce supply and demand imbalances throughout the Basin,
- Analysis of supply and demand relationships and quantification of imbalances in specific locations throughout the Basin,
- Development and evaluation of options for balancing supply and demand,
- Findings and recommendations,
- Description of methods and research processes, including assumptions, models and data used in the Study, and
- Description of stakeholder involvement.

Other expected outcomes include the identification of collaborative strategies through the Study's stakeholder involvement process.

1.3.4 Public Involvement Plan

A Public Involvement Plan has been developed to ensure that all stakeholders in the Basin as well as the general public are informed and their input is sought and considered throughout the Study. The Public Involvement Plan is provided in appendix 4.

Appendix 2
Previously Published Study Documents

Appendix 2 — Previously Published Study Documents

This appendix presents a list of Colorado River Basin Water Supply and Demand Study (Study) reports that were previously published. Due to the inherent complexities of the Study and the many diverse interests and perspectives of the various stakeholders, interim reports and technical updates were published to reflect continual technical developments and the ongoing input of stakeholders.

In June 2011, the Study published its first set of reports, Interim Report No. 1, which documented the Study's progress through January 31, 2011. This publication was comprised of six elements:

- **Executive Summary:** Provided a summary of the Interim Report.
- **Status Report:** Provided an overview of the Study and summaries of the Technical Reports.
- **Technical Report A – Scenario Development:** Described the scenario planning approach used to incorporate uncertainty in future water supply and demand.
- **Technical Report B – Water Supply Assessment:** Described the water supply scenarios and presents the analysis and comparison of those scenarios.
- **Technical Report C – Water Demand Assessment:** Described the water demand scenarios currently under development and presents the historical consumptive use for the period 1971 through 2008.
- **Technical Report D – System Reliability Metrics:** Described the metrics that have been identified for use in the assessment of reliability of the system to meet the needs of the resources under future supply and demand scenarios.

In December 2011, the Study published a report during the initiation of the final phase of the Study: Development and Evaluation of Opportunities for Balancing Water Supply and Demand. This publication was comprised of one element:

Phase 4: Development and Evaluation of Opportunities for Balancing Water Supply and Demand: Provided relevant information to those interested in submitting input. This report also provided a background of the past studies that have assessed future imbalances and explored options and strategies, and describes ongoing efforts for balancing supply and demand.

In February 2012, the Study published updated reports to reflect the comments received on Interim Report No. 1, technical developments, and the ongoing input of stakeholders. This publication was comprised of two elements:

- **Technical Report B – Water Supply Assessment:** Described the water supply scenarios and presents the analysis and comparison of those scenarios.

- **Technical Report D – System Reliability Metrics:** Described the metrics that have been identified for use in the assessment of reliability of the system to meet the needs of the resources under future supply and demand scenarios.

In May 2012, the Study published a memorandum that updated information regarding future water demand scenarios previously published in narrative or “storyline” format in *Technical Report C – Water Demand Assessment*. This publication was comprised of one element:

- **Technical Memorandum C – Quantification of Water Demand Scenarios:** Presented the quantification of those water demand scenarios, contained a summary of the process to quantify the scenarios, the resulting Colorado River demand across the scenarios, and updates the methods and results of assessing the potential effects of a changing climate on water demand. The appendices presented additional information specific to state and tribal demand as well as projected climate change impacts.

Appendix 3
Summary of Past
Colorado River Planning Studies

Appendix 3 — Summary of Past Colorado River Basin Planning Studies

1.0 Introduction

Throughout the 20th century, the challenges and complexities of ensuring a sustainable water supply and meeting future demand have been recognized. These challenges are documented in numerous studies conducted by the Bureau of Reclamation (Reclamation) and the Colorado River Basin States (Basin States ¹) over the past 70 years. Studies done in the early half of the 20th century were focused on development of Colorado River resources. Starting in the 1960s, Basin studies continued to focus on development, but with an eye towards water supply and demand imbalances and potential means of resolving those imbalances. There was an increasing emphasis on improving the efficiency of the operation of Colorado River reservoirs and increasing the level of predictability needed by entities that receive Colorado River water to better plan for and manage available water supplies. Studies following the comprehensive framework studies of the early 1970s have all acknowledged an imbalance between water supply and demand in the Colorado River Basin (Basin). Most of these studies have not sought to explicitly quantify the imbalance, but rather have focused on potential solutions to various problems throughout the Basin, including the problems of water supply and demand imbalances, salinity, and federally recognized tribes (tribes) water rights, to name a few. In light of the attention given to some of these issues, institutional changes, such as interim operating criteria and the Consolidated Decree, have occurred.

Studies 1946 - 1952

Studies performed in the early half of the 20th century were focused on development of Colorado River resources. The studies coming out of this period led to legislation finalizing the rights of each of the seven Basin States to Colorado River water, and provided the foundation for development of storage projects throughout the Basin. The following sections summarize the studies to come out of this period.

1.1.1 *The Colorado River: A Comprehensive Report on the Development of the Water Resources of the Colorado River Basin for Irrigation, Power Production, and Other Beneficial Uses in Arizona, California, Colorado, Nevada, New Mexico, Utah, and Wyoming – 1946*

The purpose of this 1946 report by Reclamation was to provide a Basin-wide perspective for planning water development throughout the Basin. It provided an inventory of 134 potential projects, and was

intended to serve as a medium through which Congress may be appraised of the potentialities for the development of the basin's water resources and as a guide in the selection of projects that ultimately will comprise the comprehensive plan for the utilization of the waters of the Colorado River

¹ Arizona, California, Colorado, New Mexico, Nevada, Utah, and Wyoming.

system for irrigation, electrical power, and other purposes (Reclamation, 1946).

The report advocated for a comprehensive, Basin-wide plan for development as well as complete control and utilization of water of the Colorado River. It did not advocate for any particular projects to be authorized; however, it pointed out a number of issues that needed to be resolved before the selection of any projects could occur. In particular, it noted that

...before such a selection of projects can be made it will be necessary that the seven Basin states agree upon their respective rights to deplete the water supply of the Colorado River or that the courts apportion available water among them (Reclamation, 1946).

As a result, the report provided a basis for compact negotiations among the Upper Basin States, which resulted in the passage of the Upper Colorado River Compact (Compact) in 1948 (63 Stat. 31).

1.1.2 *Final Report, Engineering Advisory Committee to Upper Colorado River Basin Compact Commission – 1948; and Report on Water Supply of the Lower Colorado River Basin, Project Planning Report – 1952*

These are data-oriented reports intended to support potential development projects. After the 1946 report was published, it was concluded that more-detailed data regarding the average natural flow of streams and rates of water use were needed to serve as the basis for planning future developments for the maximum use of available water supplies. The purpose of the reports was to fill a need for a comprehensive analysis of the water supply of the Upper Basin and Lower Basin, respectively.

Both reports summarize data over the period 1914 to 1945. This period was chosen because it was believed to be a representative period of average stream flow as well as a period for which sufficient reliable hydrologic data were available to make a comprehensive analysis of water resources and stream depletions. Furthermore, the 1914 to 1945 period included the above-average runoff years from 1914 to 1929, as well as the drought years from 1931 through 1940, and was therefore thought to be appropriate for considering storage problems of stream flow in drought years.

Together, these reports provide a basis for a comprehensive analysis of the water supply of the entire Basin.

1.1.3 *Colorado River Storage Project and Participating Projects, Upper Colorado River Basin - 1950*

The *Colorado River Storage Project (CRSP) and Participating Projects* report outlined a plan of development in the Upper Colorado River Basin and recommended an initial construction program (Reclamation, 1950). The plan contained three fundamental elements: 1) reservoir storage, to conserve and regulate stream flows, and to generate power, 2) participating irrigation projects, made possible by the storage reservoirs, and 3) the Upper Colorado River Account, to be charged with scheduled payments on the construction, operations and maintenance, and replacement costs of the CRSP and participating projects.

In this report, an ultimate storage plan was envisioned that would permit full utilization by the Upper Basin of the 7.5 million acre-feet (maf) of water apportioned to the Upper Basin under the Compact. The storage capacity contemplated was designed to assure that the flow of the river at Lees Ferry would not be depleted below 75 maf in any 10 consecutive years. The goal was to provide the infrastructure with which the Upper Basin could proceed safely with use of its waters, and the Lower Basin would be assured that its rights under the Compact were protected (Reclamation, 1950).

Given the analysis of Colorado River supplies (primarily taken from the 1948 report by the Engineering Advisory Committee, but expanded to include data through 1947) and assumptions of Upper Basin depletions, the greatest 10-year flow deficiency at Lees Ferry was projected to be 20.8 maf for the period ending in 1940 (see table 1). More-detailed studies based on monthly data rather than on the annual data used in the table indicated an imbalance of 23 maf for the 1931 to 1940 decade, indicating a need for that amount of storage capacity for river regulation. Therefore, according to the plan outlined in the CRSP report, 23 maf would be reserved in project reservoirs for long-time regulatory storage. The water stored would be released as needed in drought periods to meet the Compact obligation at Lees Ferry.

Studies 1964 – 1972

Starting in the 1960s, Basin studies continued to focus on development, but with an eye towards water supply and demand imbalances and potential means of resolving those imbalances. Increasing emphasis was placed on improving the efficiency of the operation of Colorado River reservoirs and increasing the level of predictability needed by entities that receive Colorado River water to better plan for and manage available water supplies. The following sections summarize the studies to come out of this period.

1.1.4 Pacific Southwest Water Plan - 1964

The *Pacific Southwest Water Plan* was the first study to project a water supply and demand imbalance in the Basin (Reclamation, 1964). The report outlined a two-phase plan of action designed to meet the immediate and long-range water needs of the Pacific Southwest, defined in this report as the water service area of the Lower Colorado River Basin including southern California. In both phases, substantial emphasis was placed on the salvage of water and more-efficient water use, although the plan also called for the importation of water to make up the remaining imbalance.

Based on estimates of the rate at which the Upper Basin will develop uses for its apportioned share of Colorado River water, it is estimated that by the year 2030, in the absence of measures to increase Lower Basin water supplies, the amount of water available from the Colorado River at and below Hoover Dam for consumptive use by the Lower Basin States will decrease to 5,620,000 acre-feet annually. This would be 1,880,000 acre-feet below the 7,500,000 acre-feet divided among the Lower Basin States by the recent decision of the Supreme Court in the case of *Arizona v. California*. To make up this deficiency, through the 7,500,000 acre-foot guarantee, the Initial Plan provides for water salvage and related works to yield 680,000 acre-feet

annually and for import of the remaining deficiency of 1,200,000 acre-feet (Reclamation, 1964).

TABLE 1
Determination of Active Storage Requirement

DETERMINATION OF ACTIVE STORAGE REQUIREMENT TO PERMIT FULL UTILIZATION OF APPORTIONED CONSUMPTIVE USE Unit: 1,000 acre-feet					
Water year	1 Virgin flow of Colorado River at Lee Ferry	2 Ultimate use of upper basin apportionment ^{1/}	3 Ultimate depleted unregulated flow at Lee Ferry (Col.1 minus Col.2)	4 Ten-year moving total flow at Lee Ferry	5 Ten-year variation from 75 million acre-feet
1914	21,220	9,030	12,190		
1915	14,030	6,910	7,120		
1916	19,200	8,860	10,340		
1917	24,040	9,530	14,510		
1918	15,360	7,920	7,440		
1919	12,460	6,560	5,900		
1920	21,950	9,370	12,580		
1921	23,020	9,470	13,550		
1922	18,310	8,180	10,130		
1923	18,270	8,450	9,820	103,580	+28,580
1924	14,200	7,340	6,860	98,250	+23,250
1925	13,030	6,860	6,170	97,300	+22,300
1926	15,850	7,770	8,080	95,040	+20,040
1927	18,620	8,630	9,990	90,520	+15,520
1928	17,280	8,390	8,890	91,970	+16,970
1929	21,430	8,670	12,760	98,830	+23,830
1930	14,890	7,590	7,300	93,550	+18,550
1931	7,770	5,330	2,440	82,440	+ 7,440
1932	17,240	7,950	9,290	81,600	+ 6,600
1933	11,360	6,500	4,860	76,640	+ 1,640
1934	5,640	4,480	1,160	70,940	- 4,060
1935	11,550	6,450	5,100	69,870	- 5,130
1936	13,800	7,480	6,320	68,110	- 6,890
1937	13,740	6,710	7,030	65,150	- 9,850
1938	17,550	7,840	9,710	65,970	- 9,030
1939	11,080	6,260	4,820	58,030	-16,970
1940	8,600	5,130	3,470	54,200	-20,800
1941	18,150	7,700	10,450	62,210	-12,790
1942	19,120	7,830	11,290	64,210	-10,790
1943	13,100	7,070	6,030	65,380	- 9,620
1944	15,150	6,980	8,170	72,390	- 2,610
1945	13,410	6,740	6,670	73,960	- 1,040
1946	10,420	5,950	4,470	72,110	- 2,890
1947	15,470	7,510	7,960	73,040	- 1,960
Means:					
1931-40	11,830	6,410	5,420		
1914-45	15,640	7,500	8,140		

^{1/}Use apportioned by Colorado River Compact, measured in terms of man-made depletions at Lee Ferry.

Source: CRSP report, 1950

In this study, importation of water from northern California was suggested to meet the imbalance. The initial plan contemplated the conveyance of 1.2 maf of surplus water from northern to southern California to guarantee against deficiencies in water supplies available from the lower Colorado River (Reclamation, 1964).

This study led to the enactment of the Colorado River Basin Project Act of September 30, 1968 (Public Law 90-537), making the Central Arizona Project (CAP) a reality.

1.1.5 Water Supplies of the Colorado River – 1965

The recommendations and requests for authorization contained within the 1964 *Pacific Southwest Water Plan* caused concern in the Upper Basin, particularly regarding the CAP. Consequently, the Upper Colorado River Commission sponsored a study in 1965 by consulting engineers Tipton and Kalmbach. The results of this study were presented in *Water Supplies of the Colorado River* (Tipton, 1965).

This study concluded that Upper Basin consumptive use, including evaporation, would be limited to 6.3 million acre-feet per year (maf). Net depletion excluding evaporation would be 5.6 maf. A water supply and demand imbalance was calculated to be 1.195 maf (See figure 1).

FIGURE 1
Analysis of Lower Basin Supply and Demand and Resulting Deficiency

Lower River Requirements:		
1. Beneficial consumptive use by Arizona, California and Nevada	7.500 maf	
2. Mexican Treaty Deliveries	1.500	
3. Reservoir Evaporation	0.730	
4. Losses below Hoover Dam	0.810	
Total Requirements		10.540 maf
Water Supply for the Lower River:		
1. Delivery at Lee Ferry	8.250 maf	
2. Net Inflow Lee Ferry to Lake Mead	0.675	
3. Net Inflow from Bill Williams River	0.055	
4. Release from Lake Mead (drawdown to rated power head)	0.365	
Total Water Supply		9.345
Deficiency		1.195 maf

Source: Tipton, 1965.

The study states that, although a delivery of 8.25 maf had been assumed, the amount delivered by the Upper Basin eventually would approximate 7.5 maf. When the delivery from the Upper Basin lowered to 7.5 maf instead of 8.25 maf, then the deficiency would increase to 1.945 maf. Likewise, if the provisions of Section (b) of Article IV of the Compact were invoked, Lake Mead could be drawn down to absolute dead storage, which would provide about 0.60 maf of additional water, including a decrease in evaporation from Lake Mead. In this case, the above deficiencies would be reduced by about 0.60 maf (Tipton, 1965).

Finally, the study suggested the importation of water to meet the imbalance. It comes short of recommending a particular source of importation, stating:

The obvious conclusion is that a firm water supply is not available in the Colorado River to satisfy a basic beneficial consumptive use requirement of 7.5 maf from the main stem by Arizona, California and Nevada, plus delivery of 1.5 maf of water to Mexico. If these requirements as well as Upper Basin requirements are to be satisfied, projects must be authorized and constructed to import major amounts of water into the Colorado River Basin from sources of surplus. Such importation is important to both the Upper and Lower Basins (Tipton, 1965).

1.1.6 The Comprehensive Framework Studies – 1971-1972

Three Comprehensive Framework Studies were conducted that pertain to the Basin – the Lower Colorado Region Comprehensive Framework Study, the Upper Colorado Region Comprehensive Framework Study, and the California Region Comprehensive Framework Study (Pacific Southwest Inter-agency Committee, 1971a, 1971b, and 1972). As defined in these framework studies, the Lower Colorado Region consisted of those parts of the Lower Colorado River Basin which lies downstream of Lees Ferry except for parts of the Lower Basin lying in California (e.g., west of the Colorado River). Parts of California lying within the Lower Colorado Basin were covered in the California Region Comprehensive Framework Study. The objective of the framework studies was to provide a broad guide to the best use, or combination of uses, of water and related land resources in each region to meet foreseeable short- and long-term needs.

Each of the framework studies had multiple demand scenarios, predominantly based on 1968 national population and demographic projections by the Office of Business Economics of Commerce, and the Economic Research Service, U.S. Department of Agriculture (OBERS). These projections were then modified to reflect local conditions.

Each of the studies detailed the status of development as of the base year, 1965. The studies then presented a framework program for the development and management of the water and related land resources (Framework Plan) of the respective region through 2020.

1.1.6.1 Lower Colorado Region Comprehensive Framework Study – 1971

Two demand scenarios were considered in the formulation of the Lower Colorado Region Comprehensive Framework Study: 1) the Base Plan, based on the regionally interpreted OBERS projections, and 2) the non-modified OBERS projections.

The basic long-range objective of this study was augmentation of the region's water supplies in sufficient increments to meet future water requirements and reduce ground water overdraft. The Framework Plan consisted of an Early Action Program to cover short-term requirements (1965 to 1980), and a Continuing Program to cover longer-term requirements (1981 to 2020). The most critical immediate need was identified as meeting the diversion requirements projected to occur before 1980 without increasing the groundwater overdraft.

After implementation of the Early Action program, a water supply deficiency of about 1.5 maf was projected to remain. Therefore, the framework program provided for the importation of 2.25 maf of desalted sea water to the Lower Colorado Region before 2000, including 1.8 maf to satisfy the 1944 Treaty with Mexico Mexican Treaty requirement and 0.45 maf as a regional program. Imported water would be conveyed to and stored in Lake Mead. It was

projected that, if the initial water importation were in operation at year 2000, a regional annual water deficiency of about 0.44 maf would remain, which would increase to about 2.1 maf annually by 2020. The framework recommended additional importation facilities between 2000 and 2020 to provide about 1.9 maf annually, reducing the annual imbalance to 0.17 maf by 2020. In the absence of an imported water supply, groundwater overdraft was expected to continue and the regional water deficiency was projected to reach 4.5 maf by 2020.

1.1.6.2 *Upper Colorado Region Comprehensive Framework Study – 1971*

In the Upper Colorado Region Comprehensive Framework Study, four demand scenarios were analyzed: 1) the Base Plan, based on the regionally interpreted OBERS, 2) the States' alternative to the Framework Plan (6.55 maf level of development), 3) States' alternative at the 8.16 maf level of development, and 4) States' alternative for water supply physically available in the region (9.44 maf).

Land and water supply were not considered to be limiting factors in the Framework Plan in meeting the regionally interpreted OBERS level of development; however, the study concluded that the future outflow at Lees Ferry would depend on which level of development actually occurred, as well as augmentation. Augmentation practices considered as possibilities included water-yield improvement and weather modification, which were thought to increase the water supply by about 1 to 2 maf. The study concluded that 1) augmentation would definitely be required by 2020 for the two highest levels of depletion to meet the Compact obligation to the Lower Basin, and 2) local shortages in the region could occur at any level of development.

1.1.6.3 *California Region Comprehensive Framework Study – 1972*

Two subregions in the California Region Comprehensive Framework Study are pertinent to the Basin—the Colorado Desert and the South Coast subregions. Three demand scenarios were analyzed in this study: 1) the Base Plan, based on the locally interpreted OBERS projections, 2) the non-modified OBERS projections, and 3) Series D-1970 projections used in a California state study, which projected a population of 45 million (10 million less than the OBERS projections).

A number of alternatives were presented for meeting projected needs. The report states that:

Three general approaches were taken in developing alternatives for meeting water supply requirements or to produce the goods and services dependent on water supply. These are: first an approach that relies on surface water development; second, an approach that utilizes other means for providing water supply; and third, an approach that reduces water requirements...When programs are finally implemented they will likely contain elements from each of the three approaches (Pacific Southwest Inter-Agency Committee, 1972).

In the Colorado Desert subregion, the study noted that water, not land, is the limiting factor in future development. The study predicted that 675,000 acres would be under irrigation by the year 2020; however, if water were readily available within the service area of the Colorado River, an additional 330,000 acres of new land could be utilized. Although the possibility of developing this additional acreage was not considered, it was believed that at

least an additional 1.5 maf of water could be used in this area if it were available (Pacific Southwest Inter-Agency Committee, 1972).

The South Coast subregion was projected to have a water supply and demand imbalance of 1.64 maf by 2020. The study suggested this imbalance would need to be resolved through sources such as reuse of surface and ground waters, waste water reclamation, distillation, and development of new supplies outside of the area. Waste water reclamation of 560 thousand acre-feet per year was included as a plan element for the South Coast subregion. Importation of North Coastal water supplies was necessary to meet Base Plan projections, but not OBERS or Series D-1970 projections.

Studies 1975 - 2007

Studies following the Comprehensive Framework Studies have all acknowledged an imbalance between water supply and demand in the Basin. Most of these studies have not sought to explicitly quantify the imbalance, but rather have focused on potential solutions to various problems throughout the Basin, including the problems of water supply and demand imbalances, salinity, and tribal water rights. In light of the attention given to some of these issues, institutional changes, such as interim operating criteria and the Consolidated Decree, have occurred. The following sections summarize what these more-recent Basin studies have concluded about water supply and demand imbalances.

1.1.7 *Westwide Study Report on Critical Water Problems Facing the Eleven Western States - 1975*

The *Westwide Study Report on Critical Water Problems Facing the Eleven Western States* (Reclamation, 1975) was an interagency state-federal effort meant to provide the information necessary to assist the federal government in making decisions on policy, funding, and action programs for development of the West's water resources.

The principal conclusions regarding water supply and demand imbalances were that the Colorado River should be able to meet all quantitative physical water demands for some years to come; however, assuming a long-term average annual supply of 14.9 maf, sometime after the CAP became fully operational the Colorado River would not yield enough water under normal circumstances to meet Upper and Lower Basin demands, Mexican Treaty obligations, and system losses. Therefore, the study concluded, the Basin faces future water shortages unless its natural flows are augmented or Basin development is curtailed. Assuming a fairly intensive level of future Upper Basin development and a conservative long-term hydrologic cycle, the study predicted the Colorado River water supply would not meet all water demands, beginning in about 1990, and shortages would become progressively greater thereafter. The extent and timing of these shortages would depend on the rate of future consumptive use development and the volumes of annual runoff (Reclamation, 1975).

The study continued to discuss potential options for a total water management program. It envisioned a program that would include activities such as:

- Coordinated operations of all major structures and conjunctive use of surface and groundwater supplies
- Increasing irrigation efficiency through such means as better on-farm system and management practices and improved distribution systems
- Waste water reclamation and reuse
- Increasing water yield through selective phreatophyte removal and control, reducing snowpack evaporation, and watershed management practices
- Reallocation of water supplies through institutional procedures
- Water pricing mechanisms

The study ultimately concluded:

It is evident that a total water management program can only delay and not prevent water shortages from occurring eventually. When such shortages do occur there appears to be two alternative courses open. The first would be to accept the limitation in water supply and pattern the economic and social future of the basin to that limitation. The second option would be to augment the flows of the Colorado River thus increasing its water supply and permitting continued growth of water dependent developments (Reclamation, 1975).

1.1.2 Colorado River Basin Water Problems: How to Reduce the Impact - 1979

This report, by the Government Accounting Office, described numerous water problems existing within the Basin and discussed the need for the states and the federal government to work together to solve these problems. One of the key problems addressed is that “water supply is insufficient to meet future demands” (Government Accounting Office, 1979).

The study’s discussion of water supply included Reclamation’s estimate of average annual natural flow and three challenging estimates. Reclamation’s estimate, based on records dating 1906 through 1977, was 14.8 mafy. Alternative estimates of average annual natural flow came from 1) the Upper Colorado River Commission, which stated that it considered the gauged records for 1922 1977 to be more reliable and accepted the estimate of 13.7 maf as the future annual virgin flow, 2) engineers from the Lower Basin States, who testified before Congress during hearings for the 1968 Colorado River Basin Project Act that the virgin river flow was between 13.7 and 14.0 mafy, and 3) researchers at the Laboratory of Tree Ring Research, University of Arizona, who used tree ring reconstructions to estimate the river’s annual flow to be about 13.5 mafy.

The report quoted Reclamation studies indicating that a water supply and demand imbalance could occur as early as 1992 and probably would occur before 2023. It concluded that after the CAP came online, the river would probably not yield enough water to meet all Basin

demands, the Mexican Treaty obligations, and river system losses. It further concluded that, unless the water supply available to CAP were increased, farmland would have to be reduced significantly to balance water supply and use by 2020, assuming median growth rate in nonagricultural activities.

Suggested solutions to the predicted imbalance included water salvage programs, conservation, and various augmentation methods. Water salvage measures included dredging the river channel, removing vegetation along the river bank, construction of Senator Wash Dam to improve control of the flow of water to the United Mexican States (Mexico) by reducing excess deliveries, and installing wells near the border to reduce the flow of groundwater to Mexico. Conservation measures primarily focused on farming efficiency. Augmentation methods considered included weather modification, vegetation management, desalting geothermal brines and sea water, and importation of water from other river basins.

Finally, the report included three recommendations to the Secretary of Interior for addressing water supply and demand imbalances, referred to as shortages in the report:

1. Direct Reclamation to develop a series of water management plans that reflect various supply estimates and present a number of alternative actions. Coordinate these plans with all the Basin's water managers.
2. Amend reservoir operating criteria by stating 1) the conditions under which a water supply shortage will be declared, 2) the amounts to be released during a shortage, 3) the reservoir storage levels to be maintained in low-flow years, and 4) the amount of water each subbasin must provide for the 1944 Treaty with Mexico commitment.
3. Direct Reclamation to develop a comprehensive plan specifying the conservation, water salvage, and augmentation techniques that will be used to prevent or minimize the adverse effects of shortages. This plan should identify factors that would interfere with implementing the plan and address how they would be resolved.

1.1.3 Colorado River Basin Study – 1997

This study was requested by the Western Water Policy Review Advisory Commission (Commission), and completed by Dale Pontius. It included analysis of the most critical issues projected to be facing the basin in the near future, efforts being made to address these problems, and specific recommendations to the Commission for Basin water management and governance over the next 20 years. The study conceptualized a vision for the Basin for the year 2025, the basic premise of which was that

...we should be working toward three general goals in developing water policy for the basin in the next century: they are equity, efficiency, and sustainability in water use and management (Pontius, 1997).

Regarding water supply and demand imbalances, the analysis depended on previous studies for information, and concluded that the river was over-allocated by 20 to 30 percent, depending on which flow estimates were used. The report stated that for planning purposes in the Upper Basin, the Upper Colorado River Commission had used 6.0 mafy as full development. Based on this number, current depletions in the Upper Basin (including 520,000 acre-feet per year of reservoir evaporation) were already more than 75 percent of the

available amount, and projections showed that the Upper Basin states would be using 90 percent of 6.0 mafy by the year 2030. The study further concluded that in the Lower Basin, implementation of the Arizona Water Bank would mean that Arizona would divert its full apportionment as early as 1998 and that Nevada would be using its full 300,000 af apportionment by 2010.

Included in the recommendations to address water supply and demand imbalances were the following:

- An interstate water bank should be established in the Lower Basin with maximum flexibility for marketing and banking water.
- The Basin States and local water managers need to develop stronger conservation programs to maximize conservation and reuse potential and more clearly define and regulate reasonable beneficial use.
- The Secretary, Basin States, and tribes, with input from other interests, should agree on a plan for reservoir operation and surplus and shortage criteria that is equitable to all interests and meets federal statutory obligations and treaty obligations to Mexico.

1.1.4 Colorado River Basin Water Management: Evaluating and Adjusting to Hydroclimatic Variability - 2007

This report was prepared by the Committee on the Scientific Bases of Colorado River Basin Water Management. The activities of this committee were overseen and supported by the National Research Council's Water Science and Technology Board. The committee was asked to review the hydrologic and climatic bases of Colorado River water management and to consider broad topics of system operations and water management practices. Terms such as "population growth" and "water demand" did not appear in the statement of task.

Nonetheless, as the committee proceeded,

...it became clear that broad understanding of Colorado River management issues is not possible unless both water supply and demand issues are adequately considered. Thus [they] felt it incumbent to comment on topics of water demand, technologies and practices for augmenting water supplies, and programs for coping with drought" (Committee on the Scientific Bases of Colorado River Basin Water Management, 2007).

Within the scope of its statement of task and its available resources, the committee chose to focus on reviewing existing scientific knowledge of hydroclimatic variability and on discussing the implications of hydroclimatic variability in the context of key water management challenges in the Basin. The committee also aimed to broadly assess key Colorado River scientific issues as they relate to water supply, demand, management, and drought preparedness.

The committee concluded that:

Technological and conservation options for augmenting or extending water supplies – although useful and necessary – in the long run will not constitute a panacea for coping with the reality that water supplies in the Colorado River

basin are limited and that demand is inexorably rising (Committee on the Scientific Bases of Colorado River Basin Water Management, 2007).

The report contained three major conclusions, based on the committee's evaluation of drought planning strategies:

- Interstate cooperation and initiative will prove increasingly valuable and essential in coping with future droughts and growing water demands.
- A commitment to two-way conversation among scientists and water managers is important and necessary in improving overall preparedness and planning for drought and other water supply shortages.
- A comprehensive, action-oriented study of Colorado River region urban water practices and changing patterns of demand should be conducted because such a study could provide a more systematic basis for water resources planning across the region. The study could be conducted by the Basin States, a federal agency or agencies, a group of universities from across the region, or some combination thereof. These groups should be prepared to take action based on this study's findings in order to improve the region's preparedness for future inevitable droughts and water shortages.

Summary and Conclusions

Previous studies of the Colorado River Basin reveal that water supply and demand imbalances have been on the radar since the 1960s. A number of useful developments have come out of these studies. For example, the *Colorado River Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lake Powell and Lake Mead Final Environmental Impact Statement* (Reclamation, 2007) partially addressed recommendations from the more-recent group of studies, by amending reservoir operations under low reservoir conditions for an interim period.

The current Colorado River Basin Water Supply and Demand Study is the next logical step in the series of studies. Such a comprehensive state-federal cooperative study has been envisioned and recommended in several of the more recent 'survey' studies, and picks up where the previous studies have left off.

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Appendix 4

Study Participants

Appendix 4 — Study Participants

As envisioned by the *Plan of Study*, teams were established to facilitate the completion of the Study. Members of each team are presented along with their affiliation.

1.0 Steering Team Members

A list of Steering Team members and their affiliations is presented below.

- Perri Benemelis, Arizona Department of Water Resources
- Carly Jerla, Bureau of Reclamation
- Dave Trueman, Bureau of Reclamation
- Chris Harris, Colorado River Board of California
- Ted Kowalski, Colorado Water Conservation Board
- Estevan Lopez, New Mexico Interstate Stream Commission
- Kay Brothers, Southern Nevada Water Authority
- Don Ostler, Upper Colorado River Commission
- Robert King, Utah Division of Water Resources
- John Shields, Wyoming State Engineer's Office
- Cathy Condon, Ten Tribes Partnership
- Jason John, Ten Tribes Partnership

2.0 Project Team Members

A list of Project Team members and their affiliations is presented below.

- Perri Benemelis, Arizona Department of Water Resources
- Don Gross, Arizona Department of Water Resources
- Deanna Ikeya, Arizona Department of Water Resources
- Les Lampe, Black & Veatch
- Klint Reedy, Black & Veatch
- Pamela Adams, Bureau of Reclamation
- Alan Butler, Bureau of Reclamation
- Carly Jerla, Bureau of Reclamation
- KayLee Nelson, Bureau of Reclamation
- Ken Nowak, Bureau of Reclamation
- James Prairie, Bureau of Reclamation
- Dave Trueman, Bureau of Reclamation
- Shana Tighi, Bureau of Reclamation
- Chuck Cullom, Central Arizona Project
- Mohammed Mahmoud, Central Arizona Project
- Greg Gates, CH2M HILL
- Armin Munévar, CH2M HILL
- Chris Harris, Colorado River Board of California

- Lindia Liu, Colorado River Board of California
- Jerry Zimmerman, Colorado River Board of California
- Dave Kanzer, Colorado River Water Conservation District
- Ted Kowalski, Colorado Water Conservation Board
- Bennet Raley, Front Range Water Council
- John Carter, Imperial Irrigation District
- Mike King, Imperial Irrigation District
- Joanna Smith, Imperial Irrigation District
- Bill Swan, Imperial Irrigation District
- Kevin Flanigan, New Mexico Interstate Stream Commission
- Estevan Lopez, New Mexico Interstate Stream Commission
- Amy Haas, New Mexico Interstate Stream Commission
- Jordan Fischbach, RAND Corporation
- David Groves, RAND Corporation
- Halla Razak, San Diego County Water Authority
- Kay Brothers, Southern Nevada Water Authority
- David Donnelly, Southern Nevada Water Authority
- Tom Maher, Southern Nevada Water Authority
- Bruce Moore, Southern Nevada Water Authority
- Colby Pellegrino, Southern Nevada Water Authority
- Larry Tamashiro, Southern Nevada Water Authority
- Bill Hasencamp, The Metropolitan Water District of Southern California
- Jan Matusak, The Metropolitan Water District of Southern California
- Demetri Polyzos, The Metropolitan Water District of Southern California
- Tom Ryan, The Metropolitan Water District of Southern California
- Bob Johnson, Water Consult Engineering and Planning Consultants
- Erin Wilson, Wilson Water Group
- John Shields, Wyoming State Engineer's Office

3.0 Study Team Members

A list of Study Team members and their affiliations is presented below.

- Les Lampe, Black & Veatch
- Klint Reedy, Black & Veatch
- Pamela Adams, Bureau of Reclamation
- Alan Butler, Bureau of Reclamation
- Carly Jerla, Bureau of Reclamation
- KayLee Nelson, Bureau of Reclamation
- Ken Nowak, Bureau of Reclamation
- James Prairie, Bureau of Reclamation
- Shana Tighi, Bureau of Reclamation
- Dave Tueman, Bureau of Reclamation
- Greg Gates, CH2M HILL
- Armin Munévar, CH2M HILL

- Jordan Fischbach, RAND Corporation
- David Groves, RAND Corporation

4.0 Water Supply Sub-Team Members

A list of Water Supply Sub-Team members and their affiliations is presented below.

- Carly Jerla, Bureau of Reclamation
- Chuck Cullom, Central Arizona Project
- Tapash Das, CH2M HILL
- Armin Munévar, CH2M HILL
- Jerry Zimmerman, Colorado River Board of California
- Robert Kirk, Navajo Nation
- John Whipple, New Mexico Interstate Stream Commission
- Mike Roberts, The Nature Conservancy
- John Gerstle, Trout Unlimited
- Steve Cullinan, U.S. Fish and Wildlife Service
- Robert King, Utah Division of Natural Resources

Additional support in the form of supplemental analysis, review, and information was provided by those listed below.

- Ben Harding, AMEC Earth & Environmental
- Ken Nowak, Bureau of Reclamation
- Jim Prairie, Bureau of Reclamation
- Levi Brekke, Bureau of Reclamation's Technical Service Center
- Subhrendu Gangopadhyay, Bureau of Reclamation's Technical Service Center
- Tom Pruitt, Bureau of Reclamation's Technical Service Center
- Joe Barsugli, University of Colorado and the National Oceanic and Atmospheric Administration

5.0 Water Demand Sub-Team Members

A list of Water Demand Sub-Team members and their affiliations is presented below.

- Perri Benemelis, Arizona Department of Water Resources
- Jim Prairie, Bureau of Reclamation
- Greg Gates, CH2M HILL
- Ted Kowalski, Colorado Water Conservation Board
- Jennifer Pitt, Environmental Defense Fund
- Jason John, Navajo Nation
- John Whipple, New Mexico Interstate Stream Commission
- Tom Maher, Southern Nevada Water Authority
- Bill Hasencamp, The Metropolitan Water District of Southern California
- Don Ostler, Upper Colorado River Commission
- Andrew Hautzinger, U.S. Fish and Wildlife Service

Alternate and/or contributing members who participated include:

- Don Gross, Arizona Department of Water Resources
- Brian Westfall, Keller-Bliesner Engineering (consultant for the Navajo Nation)
- Michael Foley, Navajo Nation
- Larry Tamashiro, Southern Nevada Water Authority
- Janet Bair, U.S. Fish and Wildlife Service
- Drew Beckwith, Western Resource Advocates

Members added in November-December 2010 include:

- Marc Waage, Denver Water
- Carole Klopatek, Fort McDowell Yavapai Nation
- Charles Vaughn, Hualapai Tribal Nation
- Darryl Vigil, Jicarilla Apache Nation

6.0 Metrics Sub-Team Members

A list of Metrics Sub-Team members and their affiliations is presented below.

- Klint Reedy, Black & Veatch
- Alan Butler, Bureau of Reclamation
- Carly Jerla, Bureau of Reclamation
- Martin Einert, Bureau of Reclamation
- Kara Gillon, Defenders of Wildlife
- Jason John, Navajo Nation
- Colby Pellegrino, Southern Nevada Water Authority
- Jan Matusak, The Metropolitan Water District of Southern California
- Robert Wigington, The Nature Conservancy
- John Shields, Wyoming State Engineers Office

Points of contact with other organizations that provided additional information are presented below.

- Nathan Fey, American Whitewater
- Katrina Grantz, Bureau of Reclamation
- Robert Radtke, Bureau of Reclamation
- Jack Barnett, Colorado River Basin Salinity Control Forum
- Norm Henderson, National Park Service
- Bill Jackson, National Park Service
- Kent Turner, National Park Service
- David Slick, Salt River Project
- Janet Bair, U.S. Fish and Wildlife Service
- Tom Chart, U.S. Fish and Wildlife Service
- Andrew Hautzinger, U.S. Fish and Wildlife Service
- Jana Mohrman, U.S. Fish and Wildlife Service
- Mike Roberts, The Nature Conservancy
- John Sanderson, The Nature Conservancy

- Xavier Gonzalez, Western Area Power Administration
- Sam Loftin, Western Area Power Administration

7.0 Options and Strategies Sub-Team Members

A list of Options and Strategies Sub-Team members and their affiliations is presented below.

- Perri Benemelis, Arizona Department of Water Resources
- Don Gross, Arizona Department of Water Resources
- Les Lampe, Black & Veatch
- Klint Reedy, Black & Veatch
- Alan Butler, Bureau of Reclamation
- Carly Jerla, Bureau of Reclamation
- Ken Nowak, Bureau of Reclamation
- James Prairie, Bureau of Reclamation
- Chuck Cullom, Central Arizona Project
- Greg Gates, CH2M HILL
- Armin Munévar, CH2M HILL
- Chris Harris, Colorado River Board of California
- Lindia Liu, Colorado River Board of California
- Dave Kanzer, Colorado River Water Conservation District
- Ted Kowalski, Colorado Water Conservation Board
- Jennifer Pitt, Environmental Defense Fund
- John Carter, Imperial Irrigation District
- Kevin Flanigan, New Mexico Interstate Stream Commission
- Estevan Lopez, New Mexico Interstate Stream Commission
- Jordan Fischbach, RAND Corporation
- David Groves, RAND Corporation
- Kay Brothers, Southern Nevada Water Authority
- Tom Maher, Southern Nevada Water Authority
- Bruce Moore, Southern Nevada Water Authority
- Cathy Condon, Ten Tribes Partnership
- Jason John, Ten Tribes Partnership
- Bill Hasencamp, The Metropolitan Water District of Southern California
- Jan Matusak, The Metropolitan Water District of Southern California
- Taylor Hawes, The Nature Conservancy
- Melinda Kassen, Trout Unlimited
- Erin Wilson, Wilson Water Group
- John Shields, Wyoming State Engineer's Office

8.0 Modeling Sub-Team Members

A list of Modeling Sub-Team members and their affiliations is presented below.

- Don Gross, Arizona Department of Water Resources
- Les Lampe, Black & Veatch

- Klint Reedy, Black & Veatch
- Alan Butler, Bureau of Reclamation
- Carly Jerla, Bureau of Reclamation
- Ken Nowak, Bureau of Reclamation
- James Prairie, Bureau of Reclamation
- Dave Trueman, Bureau of Reclamation
- Chuck Cullom, Central Arizona Project
- Mohammed Mahmoud, Central Arizona Project
- Greg Gates, CH2M HILL
- Armin Munévar, CH2M HILL
- Jennifer Pitt, Environmental Defense Fund
- Evan Bloom, RAND Corporation
- Jordan Fischbach, RAND Corporation
- David Groves, RAND Corporation
- Kay Brothers, Southern Nevada Water Authority
- Tom Maher, Southern Nevada Water Authority
- Colby Pellegrino, Southern Nevada Water Authority
- Chuck Lawler, Southern Ute Indian Tribe
- Cathy Condon, Ten Tribes Partnership
- Bill Hasencamp, The Metropolitan Water District of Southern California
- Karen Murphy, The Metropolitan Water District of Southern California
- Kevin Wheeler, Water Balance Consulting
- Erin Wilson, Wilson Water Group

Appendix 5
Public Involvement Plan

Appendix 5 — Public Involvement Plan

Note: This document was originally published as an appendix to the Plan of Study.

1.0 Introduction

The Colorado River Basin Water Supply and Demand Study (Study) has been selected to be one of three, two-year studies funded through the Bureau of Reclamation's Basin Study Program. The Study will provide a comprehensive analysis of current and future imbalances in water supply and demand projected through 2060 in the Colorado River Basin (Basin) and the adjacent areas of the Basin States (Arizona, California, Colorado, Nevada, New Mexico, Utah and Wyoming) that receive Colorado River water; potential impacts of climate variability and climate change on water supply and demand; and potential adaptation and mitigation strategies and options to resolve those imbalances. A primary objective of the Study is prioritization of identified strategies and options and the recommendation for potential future feasibility studies, Congressional authorization, environmental compliance activities, demonstration programs, and/or implementation.

The Study is cost-shared on a 50/50 basis between the Study partners: Reclamation (the Federal Cost-Share Partner) and agencies in the Basin States (the non-Federal Cost-Share Partners). Because the Colorado River Basin spans two Reclamation regions, Reclamation is represented by both the Upper Colorado Regional Office and the Lower Colorado Regional Office.

The Study partners will facilitate public involvement to solicit and incorporate stakeholder input throughout the study. This Public Involvement Plan (PIP) provides the framework for that effort.

1.1 Approach

Several communication methods will be employed to effectively maintain communication with all interested stakeholders and to provide, seek, and receive information. A response will be provided for all comments received. All information received regarding technical aspects of the Study will be considered and feedback regarding that consideration will be provided.

All outreach materials, information received, and feedback provided will be archived in a centralized electronic filing system. As the Study progresses, the effectiveness of the public involvement will be assessed periodically and adjustments will be made as necessary to ensure that appropriate communication and feedback is occurring.

1.2 Communication Methods

Effective communication is essential for the ongoing success of the Study. The methods of communication that will be used to disseminate information and accept input during the course of the Study include the following:

- Study website will be maintained to provide up-to-date, on-line information;

- E-mail address will be established to facilitate communication electronically;
- Facsimile (fax) telephone number will be established to allow communication by fax;
- Points-of-contact will be established in the Upper Colorado and the Lower Colorado Regions to facilitate additional information exchange;
- News releases and informational mailings will be provided as appropriate;
- Mailing list will be established and maintained to ensure that all interested stakeholders receive information;
- Public meetings will be held at strategic points throughout the Study; and
- Additional meetings with interested stakeholders groups will be held as appropriate.

Additional information on each of these methods is provided below.

1.3 Web Site

Reclamation's Study web site will be used to post up-to-date information. Web site content will be updated periodically, particularly at major milestones and prior to public meetings. In addition, the web site will be used as a tool for soliciting input from stakeholders. The following web page will be available no later than January 8, 2010:

<http://www.usbr.gov/lc/region/programs/crbstudy.html>.

1.4 E-mail

Reclamation has established a Study e-mail address to disseminate information regarding the Study and to receive input. The Study e-mail address is:

ColoradoRiverBasinStudy@usbr.gov.

1.5 Facsimile

Input may also be submitted by facsimile at: 702-293-8156.

1.6 Points-of-Contact

For additional information, questions, or comments on the Study, Reclamation has designated an Outreach Coordinator:

Pam Adams at 702-293-8501 or ColoradoRiverBasinStudy@usbr.gov

1.7 News Releases and Informational Mailings

News releases and other informational mailings will occur near major milestones throughout the Study to inform stakeholders and the public of the Study status, provide opportunities for input, and provide meeting information including dates and locations of the public meetings.

1.7.1 Mailing List

Informational mailings will be sent to interested stakeholders on the Study mailing list (either physically, electronically, or both). During each informational mailing, the recipient will be

asked if he or she would like to remain on the list. Individuals will be added to the mailing list when requested through the Study e-mail address or through attendance at a public meeting captured on the sign-in sheet. An initial mailing will be made in January 2010 to a list of Colorado River stakeholders who were involved in similar prior studies.

1.7.2 Public Meetings

Public meetings will be held at strategic points throughout the Study, beginning with an initial meeting in the spring of 2010. Additionally, prior to completion of each Study phase, public meetings will be held to provide a summary of the results of the previous phase and to seek comments on the upcoming phase of the Study, thereby allowing consideration of information and suggestions by the public for incorporation in the Study.

Four public meetings are currently envisioned as follows:

1. *Targeted for March 2010* - Meeting to discuss the Study objectives, structure, schedule, PIP, the proposed approach for Phase 1 (assessment of current and future water supply), and Phase 2 (assessment of current and future water demand);
2. *Targeted for September 2010* – Meeting to discuss the results of Phases 1 and 2 and the proposed approach for Phase 3 (analysis of the current and future system reliability);
3. *Targeted for April 2011* – Meeting to discuss the results of Phase 3 and the proposed approach for Phase 4 (analysis of strategies and options for resolving supply/demand imbalances); and
4. *Targeted for August 2011* – Meeting to discuss the results of Phase 4.

1.7.3 Additional Meetings with Interested Stakeholder Groups

During the course of the Study, additional meetings may be held with interested stakeholder groups to solicit additional input, expertise, data, and information. As appropriate, representatives of interested stakeholder groups may participate in specific Study tasks to facilitate incorporation of such input into the Study.

Interested stakeholder groups may include, but are not limited to Federal agencies, Native American Tribes and communities, water districts, scientific research groups, hydropower agencies and other representatives of the energy industry, environmental groups, and representatives of the recreational industry. An initial mailing will be made in January 2010 to a list of interest groups who were involved in similar prior studies to gauge their interest and capability for participating in the Study. Other interest groups are encouraged to provide their contact information via one of the communication methods listed above.

Appendix 6

Outreach Activities

Appendix 6 — Outreach Activities

This appendix presents a chronology of stakeholder outreach activities conducted for the Colorado River Basin Water Supply and Demand Study as of December 6, 2012. As summarized in table 1, a total of 173 outreach activities were conducted. The activities consisted of meetings held at locations convenient to stakeholder groups, webinars transmitted on the Internet, and telephone conference calls as shown in table 1.

TABLE 1
Stakeholder Outreach Events Conducted for Basin Study as of December 6, 2012

Meeting Date	Participant	Location	Mtg Type
3/31/2010	Conservation Organizations ¹	Boulder, CO	Meeting
5/3/2010	Conservation Organizations		Conference Call
5/25/2010	Quechan Indian Tribe, Navajo Nation, Southern Ute Indian Tribe		Webinar
5/26/2010	Hualapai Tribal Nation, Bureau of Indian Affairs - Colorado River Agency	Parker, AZ	Meeting
5/27/2010	Navajo Nation	Window Rock, AZ	Meeting
5/27/2010	Fort McDowell Yavapai Nation, Inter Tribal Council of Arizona	Phoenix, AZ	Meeting
6/16/2010	WestCAS Annual Conference	Pacific Beach, CA	Conference
6/17/2010	U.S. Fish and Wildlife Service		Webinar
6/23/2010	Bureau of Land Management	Salt Lake City, UT	Meeting
6/24/2010	Western States Water Council, Western Governors' Association		Webinar
6/25/2010	National Park Service	Las Vegas, NV	Meeting
6/30/2010	Western Area Power Administration, Salt River Project	Boulder City, NV	Meeting/ Webinar
7/9/2010	Conservation Organizations		Webinar
7/15/2010	Bureau of Land Management	Denver, CO	Meeting
7/27/2010	Conservation Organizations		Webinar
7/29/2010	Fort McDowell Yavapai Nation Tribe		Conference Call
7/30/2010	Conservation Organizations		Webinar

¹ Defenders of Wildlife, Environmental Defense Fund, Hydros Consulting, National Parks Conservation Association, Natural Resources Defense Council, The Nature Conservancy, Pacific Institute, Sonoran Institute, Trout Unlimited, Water Balance Consulting, Western Resources Advocates

TABLE 1
Stakeholder Outreach Events Conducted for Basin Study as of December 6, 2012

Meeting Date	Participant	Location	Mtg Type
8/5/2010	Hualapai Tribal Nation	Boulder City, NV	Meeting
8/10/2010	Colorado River Fish and Wildlife Council	Saratoga, WY	Meeting
8/11/2010	Ute Indian Tribe of the Uinta & Ouray Reservation	Boulder, CO	Meeting
8/18/2010	Conservation Organizations		Webinar
8/19/2010	Jicarilla Apache Nation, Ute Mountain Ute Tribe, Southern Ute Indian Tribe	Durango, CO	Meeting
8/19/2010	Conservation Organizations		Webinar
8/23/2010	U.S. Environmental Protection Agency		Webinar
9/1/2010	Conservation Organizations		Conference Call
9/3/2010	U.S. Geological Survey	Denver, CO	Meeting
9/21/2010	Hualapai Tribal Nation	Peach Springs, AZ	Meeting
9/23/2010	Colorado River Basin Study Public Meeting		Webinar
10/5/2010	Colorado Water Conservation Board	Denver, CO	Meeting
10/5/2010	Denver Water	Denver, CO	Meeting
10/6/2010	Irrigation and Electrical Districts Association of Arizona		Conference Call
10/7/2010	Front Range Water Council	Denver, CO	Meeting
10/8/2010	Inter Tribal Council of Arizona	Phoenix, AZ	Meeting
10/20/2010	Virgin River Watershed Conference	Mesquite, NV	Conference
10/28/2010	Wyoming Water Association	Laramie, WY	Meeting
10/29/2010	Front Range Water Council	Denver, CO	Meeting
11/1/2010	Conservation Organizations		Conference Call
11/1/2010	Conservation Organizations		Webinar
12/30/2010	Layne Hydro		Conference Call
1/18/2011	Conservation Organizations	Boulder, CO	Meeting
1/27/11	American Meteorological Society	Seattle, WA	Meeting
1/28/11	Tribal Leaders Water Policy Council of the Inter Tribal Council of Arizona	Tempe, AZ	Meeting
2/8/2011	Conservation Organizations		Webinar
2/8/2011	Tahoe-Baikal Institute Hydrolists group from Russia	Boulder City, NV	Conference
2/9/2011	Nevada Climate Change - UNLV	Las Vegas, NV	Conference
2/16/2011	Colorado River Indian Tribes		Conference Call

TABLE 1
Stakeholder Outreach Events Conducted for Basin Study as of December 6, 2012

Meeting Date	Participant	Location	Mtg Type
2/24/2011	Family Farm Alliance Annual Conference	Las Vegas, NV	Conference
3/2/2011	Conservation Organizations	Boulder, CO	Meeting
3/8/2011	UCLA Seminar - Colorado River Reservoir Management Under Changing Climate Conditions	Los Angeles, CA	Conference
3/21/2011	Jicarilla Apache Nation		Conference Call
3/30/2011	Southern Ute Indian Tribe	Ignacio, CO	Meeting
4/5/2011	Colorado River Indian Tribes		Conference Call
4/12/2011	Conservation Organizations		Conference Call
4/21/2011	Ak-Chin Indian Community		Conference Call
4/21/2011	Society for Human Ecology 18th International Conference	Las Vegas, NV	Conference
5/13/2011	Colorado River Indian Tribes	Parker, AZ	Meeting
5/20/2011	Society of Women Geographers Conference	Estes Park, CO	Conference
5/26/2011	American Society of Engineers - Water Resources Tech Committee	Las Vegas, NV	Conference
6/7/2011	National Climate Assessment Workshop	Boulder, CO	Conference
6/14/2011	Public Webinar - Interim Report No. 1		Webinar
6/16/2011	Jicarilla Apache Nation	Albuquerque, NM	Meeting
7/5/2011	Conservation Organizations		Conference Call
7/14/2011	Colorado Fish and Wildlife Council	Big Sky, MT	Meeting
8/2/2011	U.S. Fish and Wildlife Service	Albuquerque, NM	Meeting
8/5/2011	Tribal Leaders Water Policy Council	Phoenix, AZ	Meeting
8/11/2011	Tohono O'odham Nation	Sells, AZ	Meeting
8/17/2011	Southern Ute Indian Tribe and Ute Mountain Ute Tribe	Ignacio, CO	Meeting
8/18/2011	Conservation Organizations		Conference Call
8/23/2011	Jicarilla Apache Nation	Dulce, NM	Meeting
8/26/2011	Urban Water Institute	San Diego, CA	Conference
9/12/2011	Gila River Indian Community	Phoenix, AZ	Meeting
9/15/2011	Colorado River District Annual Water Seminar	Grand Junction, CO	Conference
9/16/2011	Conservation Organizations		Conference Call
9/16/2011	Utah League of Cities and Towns	Salt Lake City, UT	Conference
9/19/2011	Nuestro Rio	Boulder, CO	Meeting

TABLE 1
Stakeholder Outreach Events Conducted for Basin Study as of December 6, 2012

Meeting Date	Participant	Location	Mtg Type
9/19/2011	Protect the Flows		Webinar
9/20/2011	San Carlos Apache Nation	San Carlos, AZ	Meeting
9/26/2011	Ak-Chin Indian Community	Phoenix, AZ	Meeting
9/27/2011	American Water Resources Association - CO Chapter	Denver, CO	Meeting
9/30/2011	Ten Tribes Partnership	Yuma, AZ	Meeting
10/6/2011	Conservation Organizations		Webinar
10/14/2011	Conservation Organizations		Webinar
10/17/2011	White Mountain Apache Tribe	Showlow, AZ	Meeting
10/28/2011	Inter Tribal Council of Arizona	Phoenix, AZ	Meeting
10/31/2011	The Water Center at Colorado Mesa University	Grand Junction, CO	Conference
11/7/2011	American Whitewater		Conference Call
11/8/2011	Navajo Nation	Window Rock, AZ	Meeting
11/10/2011	Conservation Organizations	Boulder, CO	Meeting
11/30/2011	American Whitewater		Conference Call
12/1/2011	Conservation Organizations	Boulder, CO	Meeting
12/2/2011	U.S. Fish and Wildlife Service and The Nature Conservancy		Conference Call
12/6/2011	Public Webinar - Options & Strategies		Webinar
12/8/2011	Nuestro Rio	Denver, CO	Meeting
12/9/2011	Conservation Organizations		Conference Call
12/12-13/2011	Innovative Water Transfers Workshop	Las Vegas, NV	Conference
12/14/2011	Carpe Diem West	Las Vegas, NV	Meeting
12/14/2011	Ten Tribes Partnership	Las Vegas, NV	Meeting
12/14-16/2011	Colorado River Water Users Association	Las Vegas, NV	Meeting
12/18/2011	The Nature Conservancy and Trout Unlimited	Boulder, CO	Meeting
1/6/2012	Harvard Law School Environmental Law Program, Harvard Water Security Initiative	Boulder, CO	Briefing
1/10/2012	Carpe Diem West		Conference Call
1/18/2012	Conservation Organizations		Conference Call
1/25/2012	U.S. National Park Service		Webinar

TABLE 1
Stakeholder Outreach Events Conducted for Basin Study as of December 6, 2012

Meeting Date	Participant	Location	Mtg Type
1/26/2012	Trout Unlimited		Conference Call
1/27/2012	National Parks Conservation Association		Conference Call
1/31/2012	Carpe Diem West		Webinar
2/1/2012	Inter Tribal Council of Arizona	Phoenix, AZ	Meeting
2/2/2012	Nuestro Rio	Boulder, CO	Meeting
2/8/2012	Ten Tribes Partnership	Parker, AZ	Meeting
2/23/2012	American Bar Association, Section of Environment, Energy, and Resources' 30th Annual Water Law Conference	San Diego, CA	Conference
2/24/2012	Nuestro Rio	Denver, CO	Meeting
2/27/2012	Conservation Organizations		Conference Call
2/29/2012	U.S. Geological Survey		Conference Call
3/1-2/2012	14th Annual Law of the Colorado River Conference	Las Vegas, NV	Conference
3/6/2012	Lake Mead Symposium	Las Vegas, NV	Conference
3/8/2012	Carpe Diem West		Conference Call
3/15/2012	Conservation Organizations	Boulder, CO	Meeting
3/21/2012	Carpe Diem West		Webinar
3/22/2012	U.S. Geological Survey	Boulder, CO	Meeting
3/27/2012	Ute of Uinta and Ouray Reservation	Ft. Duchesne, UT	Meeting
3/28/2012	Ten Tribes Partnership Technical Committee	Albuquerque, NM	Meeting
4/3/2012	Conservation Organizations		Conference Call
4/4/2012	The Nature Conservancy	Boulder, CO	Meeting
4/11/2012	Ten Tribes Partnership	Towaoc, CO	Meeting
4/30/2012	Rocky Mountain Climate Organization		Conference Call
5/11/2012	Conservation Organizations	Boulder, CO	Meeting
5/21/2012	Carpe Diem West		Conference Call
5/24/2012	Conservation Organizations		Conference Call
5/29/2012	Ten Tribes Partnership	Albuquerque, NM	Meeting
6/7/2012	Conservation Organizations		Webinar
6/8/2012	Inter Tribal Council of Arizona	Phoenix, AZ	Meeting
6/13/2012	Ten Tribes Partnership	Salt Lake City, UT	Meeting
6/19/2012	Western Coalition of Arid States Conference	San Diego, CA	Conference

TABLE 1
Stakeholder Outreach Events Conducted for Basin Study as of December 6, 2012

Meeting Date	Participant	Location	Mtg Type
6/22/2012	Conservation Organizations	Boulder, CO	Meeting
7/3/2012	Western Area Power Administration		Conference Call
7/3/2012	Conservation Organizations		Conference Call
7/12/2012	U.S. National Park Service		Webinar
7/18/2012	Carpe Diem West		Conference Call
7/24/2012	Carpe Diem West	Boulder, CO	Meeting
8/1/2012	Conservation Organizations		Conference Call
8/2/2012	Flaming Gorge Recreation		Conference Call
8/15/2012	Ute Indian Tribe of the Uinta & Ouray Reservation	Fort Duchesne, UT	Meeting
8/17/2012	Conservation Organizations	Boulder, CO	Meeting
8/23/2012	Urban Water Institute	San Diego, CA	Meeting
8/28/2012	Conservation Organizations		Webinar
8/30/2012	Colorado River Fish and Wildlife Council	Steamboat Springs, CO	Meeting
9/13/2012	Colorado River District Annual Water Seminar	Grand Junction, CO	Conference
9/14/2012	Carpe Diem West	Salt Lake City, UT	Meeting
10/1/2012	Conservation Organizations		Webinar
10/5/2012	Colorado Water Conservation Board	Boulder, CO	Meeting
10/10/2012	Ten Tribes Partnership	Yuma, AZ	Meeting
10/11/2012	Conservation Organizations	Boulder, CO	Meeting
10/16/2012	Carpe Diem West		Conference Call
10/26/2012	Scripps Institution of Oceanography		Webinar
11/1/2012	National Water Resources Association	San Diego, CA	Conference
11/5/2012	Carpe Diem West	Los Angeles, CA	Meeting
11/14/2012	Carpe Diem West		Webinar
11/20/2012	Front Range Water Council	Denver, CO	Meeting
11/21/2012	Conservation Organizations	Boulder, CO	Meeting
11/26/2012	Ten Tribes Partnership		Conference Call
11/28/2012	Ten Tribes Partnership		Conference Call
12/4/2012	Ten Tribes Partnership		Webinar

TABLE 1
Stakeholder Outreach Events Conducted for Basin Study as of December 6, 2012

Meeting Date	Participant	Location	Mtg Type
12/5/2012	Family Farm Alliance		Webinar
12/6/2012	Inter Tribal Council of Arizona		Conference Call
12/6/2012	Ten Tribes Partnership		Conference Call

Appendix 7
Peer Review Summary Report

Appendix 7 — Peer Review Summary Report

1.0 Introduction

The Colorado River Basin Water Supply and Demand Study (Study), initiated in January 2010, was conducted by the Bureau of Reclamation (Reclamation) in collaboration with the seven Colorado River Basin States¹ (Basin States), conservation organizations, federally recognized tribes (tribes), and other interested parties. The *Plan of Study*, provided in appendix 1 of the *Study Report*, states that the purpose of the Study is to define current and future imbalances in water supply and demand in the Colorado River Basin (Basin) and the adjacent areas of the seven Basin States that receive Colorado River water over the next 50 years (through 2060), and to develop and analyze adaptation and mitigation strategies to resolve those imbalances. The Study contains for major phases to accomplish this goal: Water Supply Assessment, Water Demand Assessment, System Reliability Analysis, and Development and Evaluation of Options and Strategies for Balancing Supply and Demand.

This document provides a summary of the Study's peer review.

1.1 Approach

The peer review was designed to ensure that assumptions, findings, and conclusions of the Study were clearly stated and supported; oversights, omissions, and inconsistencies were identified; and limitations and uncertainties were disclosed. The reviewers were provided with focused technical questions while also being directed to offer a broad evaluation of the overall product. Specifically, peer review goals included the following:

- Improve Study reports by ensuring that the methodologies, processes, assumptions, and limitations are thoroughly described and transparent
- Understand potential critiques to help in the development of Study next steps.
- Identify any significant errors.

Peer review comments were considered and incorporated into the *Study Report* and Technical Reports where relevant and appropriate. This summary report includes the views of the reviewers, without attribution of specific comments to specific reviewers, and an explanation of the actions undertaken (or not) to address the reviewers' comments.

1.2 Peer Reviewers

The peer reviewers for this Study, as a group, have expertise in climate science and associated hydrologic impacts and water management in the Basin. Individuals with the identified expertise who did not have formal involvement in the Study were asked to participate in the independent peer review. Peer review elements and reviewers are as follows:

¹ Arizona, California, Colorado, Nevada, New Mexico, Utah, and Wyoming.

1.2.1 Water Supply Assessment

- Kelly Redmond – Deputy Director and Regional Climatologist, Desert Research Institute/Western Regional Climate Center
- Jeff Arnold – Senior Climate Scientist, U.S. Army Corps of Engineers

1.2.2 Water Demand Assessment

- Jeannine Jones – Interstate Resources Manager, California Department of Water Resources
- Bonnie Colby – Department of Agricultural and Resource Economics, University of Arizona

1.2.3 Options and Strategies

- Tom Iseman – Program Director for Water Policy, Western Governors’ Association
- James Heaney – Department of Environmental Engineering Sciences, University of Florida

1.2.4 System Reliability

- Rosalind Bark – Resource Ecological Economist, Australia’s Commonwealth Scientific and Industrial Research Organization
- Holly Hartman – Director of Arid Lands Information Center, University of Arizona

2.0 Summary of Comments

The following sections list the specific focus questions asked of the reviewers. They provide a summary of comments received, without attribution of specific comments to specific reviewers, and an explanation of the actions undertaken (or not) to address the reviewers’ comments.

2.1 Water Supply Assessment

The focus of the Water Supply Assessment peer review was whether the Water Supply Assessment met the intent of the Study. The reviewers were asked to consider the overall approach, the documentation of limitations and assumptions, and the scenario planning framework, with particular attention to secondary bias correction. The specific focus questions asked of the reviewers for the Water Supply Assessment are as follows:

1. Is purpose of the report clear?
2. Is the approach well-designed and executed?
3. Is the approach to quantifying scenarios clearly explained?
4. Has the assessment met the report goals?
5. Are the data and information appropriately cited?
6. Are assumptions and limitations explicit and justified?
7. Is the documentation accurate, understandable, clearly structured, and temperate in tone?
8. Are the reports compelling, useful, and relevant to stakeholders and decision makers?

In general, the reviewers thought the Water Supply Assessment, as detailed in *Technical Report B – Water Supply Assessment*, met all the requirements set out in the Study’s focus questions. One reviewer wrote that the report was “impressively thorough, well-planned, and very professionally executed.”

Reviewers provided specific word choice edits to clarify language and additional comments, to further strengthen the overall presentation of material. These comments focused on two topics. First, comments related to clarifying the differences between the scenarios including climate change projections and three other supply scenarios based on observed or paleo-reconstructed streamflow. Additional discussion was added to clarify that rising temperature and transient downward-trending supply were present only in the climate change scenario. In addition, discussion was added to further clarify the uncertainty associated with the future climate projections and the use of this information in water planning.

Second, comments focused on the treatment and discussion of climate teleconnections (such as the Southern Oscillation Index, El Niño Southern Oscillation, and Pacific Decadal Oscillation) and their impacts on Basin supply. In response to these comments, additional language was added to the report to elaborate and clarify the discussion on Pacific Decadal Oscillation in particular. To address general issues of clarity, additional descriptions for several figures were added, as was additional discussion on uncertainty.

2.2 Water Demand Assessment

The focus of the Water Demand Assessment peer review was whether the Water Demand Assessment met the intent of the Study. The reviewers were asked to consider the overall approach, the approach to quantifying scenarios, the documentation of limitations and assumptions, the scenario planning framework, and the assessment of climate impacts on demands. The specific focus questions asked of the reviewers for the water demand assessment are as follows:

1. Is purpose of the report clear?
2. Is the approach well-designed and executed?
3. Is the approach to quantifying scenarios clearly explained?
4. Has the assessment met the report goals?
5. Are the data and information appropriately cited?
6. Are assumptions and limitations explicit and justified?
7. Is the documentation accurate, understandable, clearly structured, and temperate in tone?
8. Are the reports compelling, useful, and relevant to stakeholders and decision makers?

In general, the reviewers thought the Water Demand Assessment, as detailed in *Technical Report C – Water Demand Assessment*, met all the requirements set out in the Study’s focus questions. One reviewer wrote, “Commendable and formidable effort to account for numerous uncertainties confronting the Basin and to integrate information from many sources pertinent to changing demand by water use sector and geographic area.”

The reviewers specified a number of perceived limitations in the Water Demand Assessment. First, reviewers pointed out that the use of conventional demographic forecasting did not consider impacts on population distribution resulting from climate change. Second, reviewers found it problematic that the use of the practically irrigable acreage approach did not consider that agricultural production (i.e., acreage and crop types) is driven by crop markets. The reviewers thought an econometric evaluation would complement the approach used in

the Study. In particular, the reviewers critiqued the exclusion of price elasticity with respect to demand, despite available studies that could have been referenced. These comments were not necessarily viewed as limitations, because the impacts on population distribution resulting from climate change, as well as the practically irrigable acreage approach, while used in academia, are not ready for use in Basin-wide planning. Although climate change was not explicitly considered with respect to demographics, the demand scenarios did include lower-growth scenarios and reflect a range of potential future populations and demographic models. The Basin States did not use practically irrigable acreage for development of agricultural demands. Agricultural demands were projected by state agencies and irrigation districts. In some cases, land use-based models were used that incorporated urban population growth and other factors. Demand elasticity was not considered explicitly in the Study; however, it was included implicitly as part of the water demand options included in the Study.

Additional comments were received requesting that the *Study Report* explain the reliance on demand information provided by the Basin States. Comments questioned whether limitations in the Study prevented gathering of independent information from sources other than state agencies on projected population, irrigated acreage, and other parameters. These comments suggested that Reclamation commit to future work to refine demand estimates through more-intensive modeling efforts of future water demands associated with agriculture and energy production. Although demand information provided by the Basin States was relied on heavily, it was not the only source of this information. Additional regional and local data were collected to supplement and support the information provided by the Basin States – particularly in consideration of alternative demand scenarios. Furthermore, the Basin States, specifically the Basin States’ representatives who were formally involved in the Study, are entrusted with the responsibility of demand planning and management in the region, therefore were the best available resource for demand planning.

2.3 Options and Strategies for Balancing Supply and Demand

The primary focus of the peer review of the options and strategies was whether the analysis met the intent of the Study. Reviewers were asked to consider the overall approach taken for options, the development and use of characterization criteria, the development and use of portfolios, and the documentation of limitations and assumptions associated with characterization. The specific focus questions asked of the reviewers for the options and strategies are as follows:

1. Is purpose of the report clear?
2. Is the approach well-designed and executed?
3. Is the approach to option development clearly explained?
4. Is the development and use of characterization criteria clearly explained?
5. Is the development and use of portfolios clearly explained?
6. Are the data and information appropriately cited?
7. Are assumptions and limitations explicit and justified?
8. Is the documentation accurate, understandable, clearly structured, and temperate in tone?
9. Are the reports compelling, useful, and relevant to stakeholders and decision makers?

In general, the reviewers thought the options and strategies, as detailed in *Technical Report F – Development of Options and Strategies*, met all the requirements set out in the

Study's focus questions. One reviewer wrote of a "sense that the Study was open-minded and receptive to new ideas and made an honest effort to provide an objective analysis."

A number of comments on this report related to the characterization of options and development of portfolios. Other comments focused on the general clarity of the report. Reviewers suggested that summary results be provided first in order to prevent the loss of the 'big picture.' They also thought the report would benefit from more citations, to help clarify assumptions. These changes were made to the final technical report.

The reviewers thought that the use of scoring criteria for the characterization of options was an overall useful exercise; however, the scoring of criteria felt "squishy" and overly precise. They pointed out that select options appeared to score more favorably than they might have deserved. For example, reviewers thought the yield estimates for weather modification and dust control options seemed high, and were surprised to see as much water yield in municipal reuse as in agricultural conservation. Additionally, reviewers thought it was not always clear which options were more tested and reliable than others. They believed that some options that had little, if any, testing or documentation scored better in terms of yield than the feasibility or reliability might suggest.

To address these comments, the report was modified to present additional summary information about the options, to aid in comparison and add clarity. With respect to specific options, in some cases, limited data were available to characterize items such as yield or cost, and there was significant uncertainty in these scores. However, the criteria associated with quantity of yield was specifically separated from those criteria associated with technical feasibility and long-term viability. Options with significant feasibility or long-term reliability concerns were rated low for these criteria, and were subsequently limited in their inclusion in portfolios that were analyzed. A risk-adjusted yield was not developed in the Study.

A number of the comments reflected a desire to know which option was "best;" however, the intent of Technical Report F was to enumerate and characterize the options without specific preferences or overall ratings. Preferences for certain option characteristics was included in the development of portfolios and the performance of these portfolios was evaluated in *Technical Report G – System Reliability Analysis and Evaluation of Options and Strategies*. In addition, the criteria were intended to be broad and represent a number of different viewpoints. Characterization alone could determine which options were "best." The analytical framework applied in the Study was intended to be essentially preference-based.

Comments regarding the development of the portfolios requested that the report explicitly define reliability, risk, and uncertainty. Reviewers thought the report was missing discussion on the methodology used for filtering through the range of choices, and requested that the report better explain the use of the Portfolio Development Tool. Last, reviewers thought that unit costs needed to be defined more precisely by including the incidence of the benefits and costs.

In order to address comments on reliability, risk, and uncertainty, the text was modified to specifically define uncertainty and refined to replace references to "risk" with "uncertainty" where the intent was the same. Discussion on the methods employed to filter and characterize options was added, and references to the Portfolio Development Tool were removed and replaced with discussion of the methods of filtering options based on the characterization criteria. As noted previously, this report did not attempt to define the efficacy or benefits of specific options, but rather provided an initial characterization that

facilitated development of a set of exploratory portfolios reflecting different strategies for addressing potential future imbalances. The results of these options and strategies are defined in *Technical Report G – System Reliability Analysis and Evaluation of Options and Strategies*. In addition, significant additional text was added to clarify the cost discussion.

2.4 System Reliability Analysis

The primary focus of the System Reliability Analysis peer review was whether the analysis met the intent of the Study. Reviewers were asked to consider the overall approach; whether there was a broad-enough set of system reliability metrics, (resource metrics, indicator metrics, signposts, and vulnerable conditions); use of system reliability metrics; and the documentation of limitations and assumptions. The specific focus questions asked of the reviewers for the System Reliability Analysis are as follows:

1. Is purpose of the report clear?
2. Is the approach well-designed and executed?
3. Are a broad set of system reliability metrics presented?
4. Are the uses of indicator metrics, signposts, and vulnerable conditions clearly explained?
5. Has the analysis met the intent of the report?
6. Are the data and information appropriately cited?
7. Are assumptions and limitations explicit and justified?
8. Is the documentation accurate, understandable, clearly structured, and temperate in tone?
9. Are the reports compelling, useful, and relevant to stakeholders and decision makers?

Technical Report G – System Reliability Analysis and Evaluation of Options and Strategies received the most extensive comments from peer reviewers. Reviewers found it particularly problematic that qualitative evaluation and discussions lacked for topics that do not lend themselves to quantitative evaluation. One reviewer thought that next steps in the analysis should include discussion on governance feasibility of options, the United Mexican States (Mexico) particularly its role in planning its future and the desire for collaborative work between the two countries), and outstanding water rights settlements associated with tribes. Another reviewer criticized the neglect of qualitative discussion of two classes of options: system operation and governance/implementation. This reviewer wrote, “This is a major short-coming because the report anchors discussion on the options that are quantitatively evaluated. Just because some options are more readily analyzed does not make them more preferred, more practical, or even more deserving of further investments (i.e., additional study), especially if choices have to be made about what options should be studied next.”

The Study acknowledges that certain options are more difficult to characterize in a structured rating approach and, in response to comments, expanded the discussion for those options that were qualitatively addressed in *Technical Report F – Development of Options and Strategies*. The *Study Report* also includes a broader discussion of the opportunities and constraints associated with the options that were qualitatively characterized in the Study. The *Study Report* includes a section on next steps that outlines the need for a cooperative approach in future efforts, including discussion on governance feasibility of options, to continue what could only be discussed qualitatively in this Study. Including discussions with Mexico and tribes and communities will be critical to the success of such an approach. At the time of the peer reviews, the *Study Report* was not yet complete or available to reviewers.

Additional comments were received that were related to other areas. First, reviewers found it problematic that results were presented in probabilistic terms, when the analysis should focus on frequency. Second, reviewers found it problematic that the analysis combined scenarios and then evaluated results that use the median as a central tendency. The reviewers thought that the use of combined scenarios for simple screening was acceptable, but not for evaluations of median behavior. Last, reviewers believed there were unanswered questions in the report, such as who would pay for the options to reduce vulnerability. To address reviewers' comments and to improve the clarity of the discussion, results from the System Reliability Analysis were modified to ensure that they were presented from the point of view of a frequency analysis. References to probability were removed where inappropriately applied. Within the discussion of System Reliability Analysis without options and strategies, the combined analysis was removed and only the 48 individual scenario combinations for supply, demand, and post-2026 Lake Powell and Lake Mead operation assumptions were presented. Clarifying language was added through the report to ensure that readers understand that the results do not describe probabilistic outcomes. Instead, they describe plausible ranges and distributions for the Baseline or a portfolio corresponding to a wide range of plausible hydrologic, demand, and management traces. The underlying traces are the same across all portfolios and therefore enable a consistent comparison of outcome differences across the portfolios.

In addition, system reliability results were presented as summaries by water supply scenario and vulnerable conditions to allow for a broader understanding of the conditions that lead to good or poor performance. Technical Report G was substantially improved based on the peer review comments and subsequent revision and analysis.

3.0 Conclusions

The peer review process was found to be a useful exercise and provided good, independent review that resulted in improvements to the technical reports included in the Study. The documents were generally well-received; the only major change was the restructuring of Technical Report G. The peer review process may have been improved by incorporating a staged review process which would engage reviewers earlier in the development of technical approaches and methods.

In general, the peer review comments indicated that the assessments had been performed adequately and the analyses met the intent of the Study. Many comments dealt with the clarity of the discussion. To address issues of clarity, discussion was added to the reports and description was added to figures and tables as necessary. Study limitations (both in terms of scope and length) prevented the more in-depth supplemental analyses that were suggested by the reviewers. Several suggestions for additional analysis are incorporated in the next steps described in the *Study Report*.