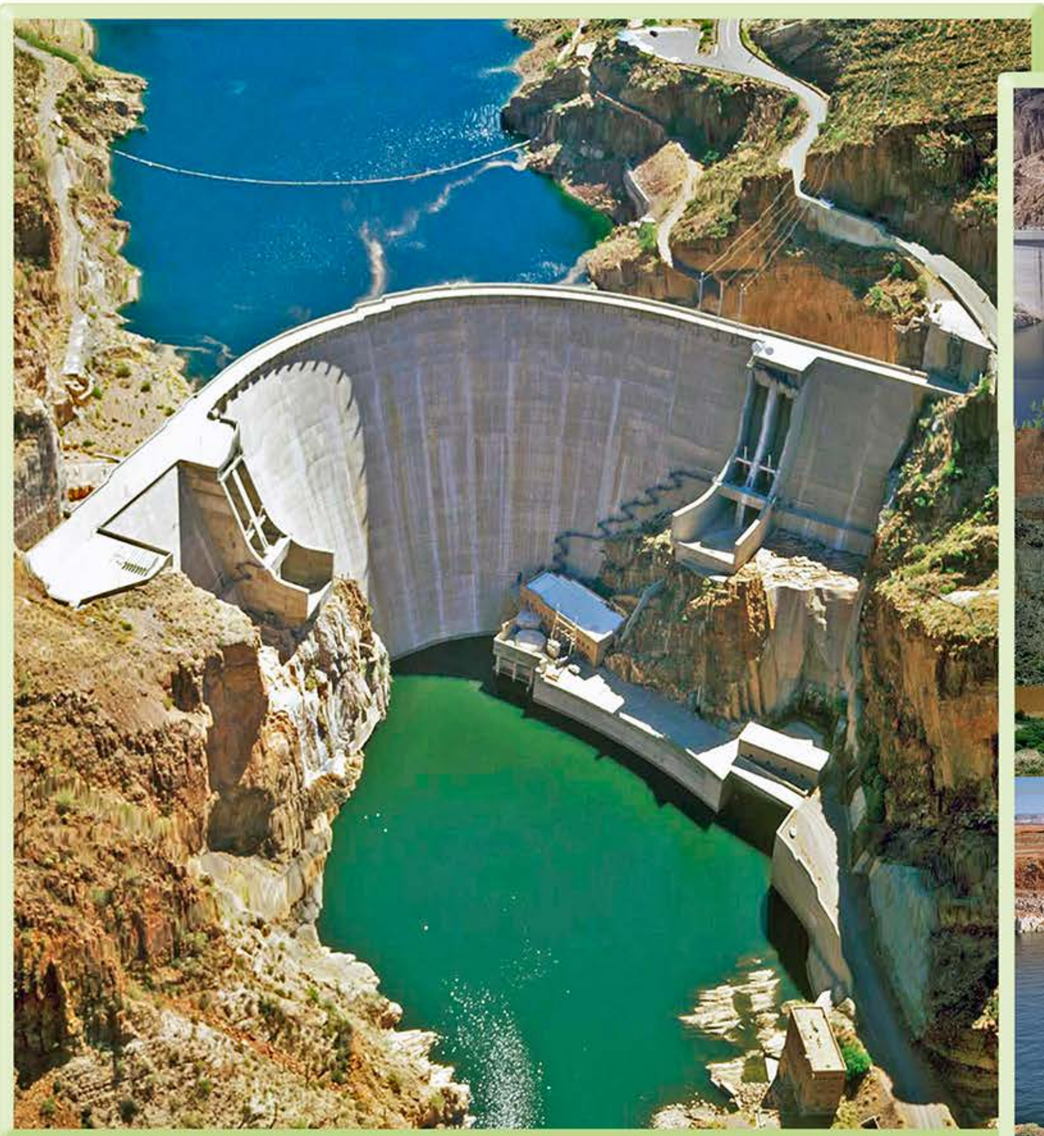
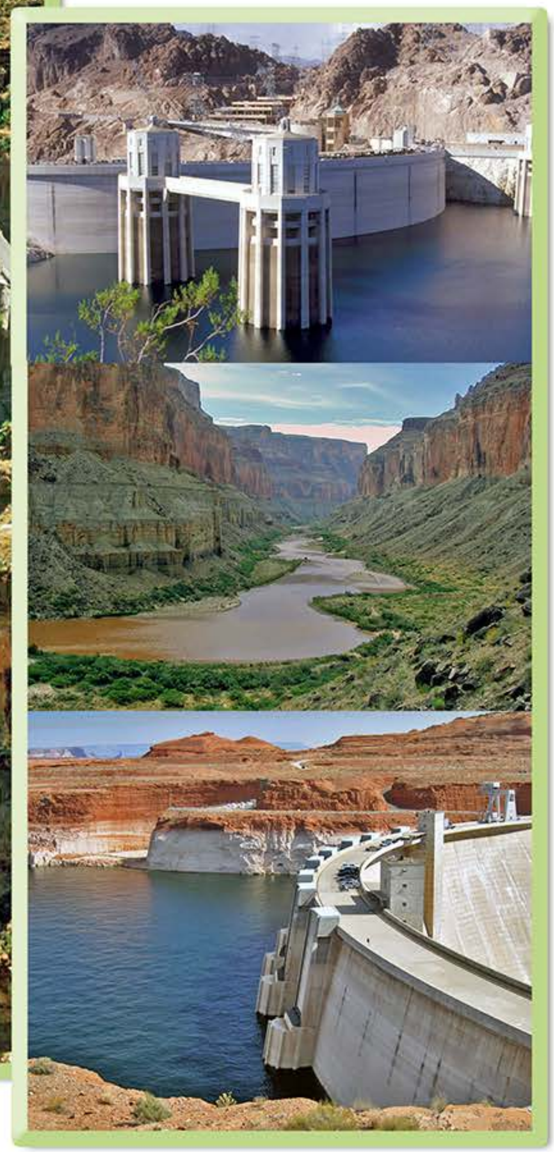
# RECLAMATION

*Managing Water in the West*

SECURE Water Act Section 9503(c)—Reclamation Climate Change and Water 2016

# Chapter 3: Colorado River Basin





U.S. Department of the Interior
Bureau of Reclamation

March 2016

## Mission Statements

The U.S. Department of the Interior protects America's natural resources and heritage, honors our cultures and tribal communities, and supplies the energy to power our future.

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

## SECURE Water Act Section 9503(c) Report to Congress

# Chapter 3: Colorado River Basin

*Prepared for*

**United States Congress**

*Prepared by*

**U.S. Department of the Interior**
**Bureau of Reclamation**

**U.S. Department of the Interior**
**Bureau of Reclamation**
**Policy and Administration**
**Denver, Colorado**

**March 2016**

# Acronyms and Abbreviations

| | |
|---|---|
| AFY | acre-feet per year |
| BWRCSC | Bill Williams River Corridor Steering Committee |
| Basin States | Colorado River Basin States |
| EIS | Environmental Impact Statement |
| LCC | Landscape Conservation Cooperative |
| M&I | municipal and industrial |
| MAF | million acre-feet |
| Mexico | United Mexican States |
| MOU | Memorandum of Understanding |
| msl | mean sea level |
| NPS | National Park Service |
| NRCS | Natural Resources Conservation Service |
| RCPP | Regional Conservation Partnership Program |
| PSCP | Pilot System Conservation Program |
| Reclamation | Bureau of Reclamation |
| TAF | thousand acre-feet |
| U.S. | United States |
| WaterSMART | Sustain and Manage America's Resources for Tomorrow |

# About this Chapter

This summary chapter is part of the 2016 SECURE Water Act Report to Congress prepared by the Bureau of Reclamation (Reclamation) in accordance with section (§) 9503 of the SECURE Water Act. The 2016 SECURE Water Act Report follows and builds on the first SECURE Water Act Report, submitted to Congress in 2011[1] , which characterized the impacts of warmer temperatures, changes to precipitation and snowpack, and changes to the timing and quantity of streamflow runoff across the West.

This chapter provides a basin-specific summary for the Colorado River Basin. This chapter is organized as follows:

- **Section 1**: Description of the river basin setting,
- **Section 2**: Overview of the implications for various water and environmental resources,
- **Section 3**: Potential adaptation strategies considered to address basin water supply and demand imbalances, and
- **Section 4**: Coordination activities within the basin to build climate resilience.

This chapter provides updated information from Reclamation studies completed or initiated in the basin over the past five years. The key studies referenced in this chapter include the Colorado River Basin Water Supply and Demand Study (Reclamation, 2012 [CO Basin Study) and the Colorado River Basin *Moving Forward* Phase 1 Report (2015 [Moving Forward]). Additional information relevant to the Colorado River Basin, including the latest climate and hydrology projections for the basin, is included in Chapter 2: Hydrology and Climate Assessment.

**Colorado River Basin Setting**

**States:** Arizona, California, Colorado, Nevada, New Mexico, Utah, Wyoming

**Major U.S. Cities Supplied:** Albuquerque, Denver, Las Vegas, Los Angeles, Phoenix, Salt Lake City, and San Diego

**Areas Outside the Basin Receiving Colorado River Water:** Albuquerque/ Santa Fe (San Juan Chama Project); Cheyenne, Wyoming; Colorado Front Range; Southern California (Colorado River Aqueduct Service Area/Imperial and Coachella Valley); and Wasatch Front Range (Central Utah Project/Strawberry Valley Project)

**International:** Mexico

**River Length:** 1,450 miles

**River Basin Area:** 246,000 square miles

**Major River Uses:** Municipal Supply (35 to 40 million people), Agricultural Irrigation (4.5 million acres), Hydropower (4,200 megawatts), Recreation, and Fish and Wildlife

**Notable Reclamation Facilities:** Hoover Dam, Glen Canyon Dam, Flaming Gorge Dam, Aspinall Unit, Navajo Dam, and Davis Dam, Parker Dam

[1] The first SECURE Water Act Report, submitted to Congress in 2011 is available on the Reclamation website: www.usbr.gov/climate/secure/docs/2011secure/2011SECUREreport.pdf.

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# 1 Basin Setting

Today, nearly 40 million people[2] in the seven Colorado River Basin states[3] rely on the Colorado River and its tributaries for some, if not all, of their municipal water needs. These same sources irrigate nearly 4.5 million acres of land (Reclamation, 2015 [Moving Forward]) in the basin and the adjacent areas that receive Colorado River water, generating many billions of dollars a year in agricultural and economic benefits. Within the basin, 22 federally recognized tribes consider the Colorado River and its tributaries an essential physical, economic, and cultural resource.

The Colorado River and its tributaries provide habitat for a wide range of species, including several that are federally endangered. These rivers flow through seven National Wildlife Refuges and 11 National Park Service (NPS) units[4] that provide a range of recreational opportunities and add significant benefits to the regional economy. Hydropower facilities in the basin can supply more than 4,200 megawatts of vitally important electrical capacity to assist in meeting the power needs of western states, reducing the use of fossil fuels. In addition, the Colorado River is vital to the United Mexican States (Mexico). The Colorado River Basin is depicted in Figure 3–1.

Total consumptive use and losses in the U.S. portion of the basin, including the 1944 Treaty delivery to Mexico, have averaged approximately 15.0 million acre-feet (MAF)[5] annually over the past decade (Reclamation, 2015 [Moving Forward]). Federally recognized tribes hold approximately 2.9 MAF of annual diversion rights from the Colorado River and its tributaries (Reclamation, 2012 [CRB Study TR-C]). In many cases, these rights are senior in priority to those held by other users. Agriculture is the dominant use of Colorado River water, accounting for approximately 70 percent of total Colorado River water used in the U.S. Of the total consumptive use, 40 percent is exported outside the basin's hydrologic boundaries for use in adjacent areas.

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[2] About 40 million people are estimated to live in the area encompassed by the hydrologic boundaries of the Colorado River Basin in the United States plus the adjacent areas of the Colorado River Basin states that receive Colorado River water (Reclamation 2012, CRB Study TR-C).

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

[4] Although there are 11 NPS Colorado River Basin Parks Program, nine are considered to be directly linked to the Colorado River and its major tributaries. (http://www.nature.nps.gov/water/Homepage/Colorado_River.cfm).

[5] Basin-wide consumptive use and losses estimated over the period 2002 to 2012, including the 1944 Treaty delivery to Mexico, reservoir evaporation, and other losses due to native vegetation and operational inefficiencies.

As shown on Figure 3–1, several major metropolitan areas that receive Colorado River water—including Albuquerque, Denver, Los Angeles, Salt Lake City, and San Diego—are located outside the basin's hydrologic boundaries.

The Colorado River system is operated in accordance with the Law of the River.[6] Apportioned water in the U.S. portion of the basin exceeds the average long-term (1906 through 2012) historical natural flow[7] of about 16.2 MAF (Reclamation, 2015 [Moving Forward]). To date, the imbalance has been managed and demands are largely met as a result of the considerable amount of reservoir storage capacity in the system (approximately 60 MAF, or nearly 4 years of average natural flow of the river); the fact that the upper-basin states of Colorado, New Mexico, Utah, and Wyoming are still developing their apportionment; and the continuing efforts the Basin States are making to reduce their need for Colorado River water.

## 1.1 Colorado River Basin Study Overview

It was against this challenging and complex management setting that the Colorado River Basin Water Supply and Demand Study was conducted. The Basin Study was funded through the Department of the Interior's WaterSMART (Sustain and Manage America's Resources for Tomorrow) Program and was conducted by Reclamation and agencies representing the Basin States. The purpose of the Basin Study was to define current and future imbalances in water supply and demand in the U.S. portion of the basin and the adjacent areas that receive Colorado River water through 2060, and to develop and analyze adaptation and mitigation strategies to resolve those imbalances.

The Basin Study did not result in a decision as to how future imbalances should or will be addressed. Rather, it provides a common technical foundation that frames the range of potential imbalances that may be faced in the future and the range of solutions that may be considered to resolve those imbalances. The Basin Study was conducted in collaboration with stakeholders throughout the basin. Interest in the study was broad, and participating stakeholders included tribes, agricultural users, purveyors of municipal and industrial (M&I) water, power users, and conservation and recreation groups.

There is great uncertainty in the precise trajectories of future water supply and demand, as well as how those trajectories may affect the reliability of the Colorado River system to meet the needs of basin resources. To address this

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[6] 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 collectively referred to as the Law of the River. There is no single, universally agreed upon definition of 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.

[7] Natural flow represents the flow that would have occurred at the location had depletions and reservoir regulation not been present upstream of that location.


**Figure 3–1. Colorado River Basin.**

**Note: The scope of the Colorado River Basin Study was limited to the portion of the basin and adjacent areas that receive Colorado River water within the United States.**

uncertainty, this Basin Study adopted a scenario planning process to capture a broad range of plausible water demand and supply futures, and then assessed the impacts to basin resources if such futures were to unfold. This approach confirmed that, absent future action, the basin faces a wide range of plausible future long-term imbalances between supply and demand. This imbalance, computed as a 10-year running average, ranges from 0 to 6.8 MAF, with a median of 3.2 MAF in 2060,[8] as shown in Figure 3–2. The assessment of impacts to basin resources found that any long-term imbalance will impair the ability of the Colorado River system to meet the needs of basin resources resulting in negative impacts (for example, reduced reliability of water deliveries for municipal and agricultural purposes, decreased hydropower generation, reduced recreational opportunities) to those resources.

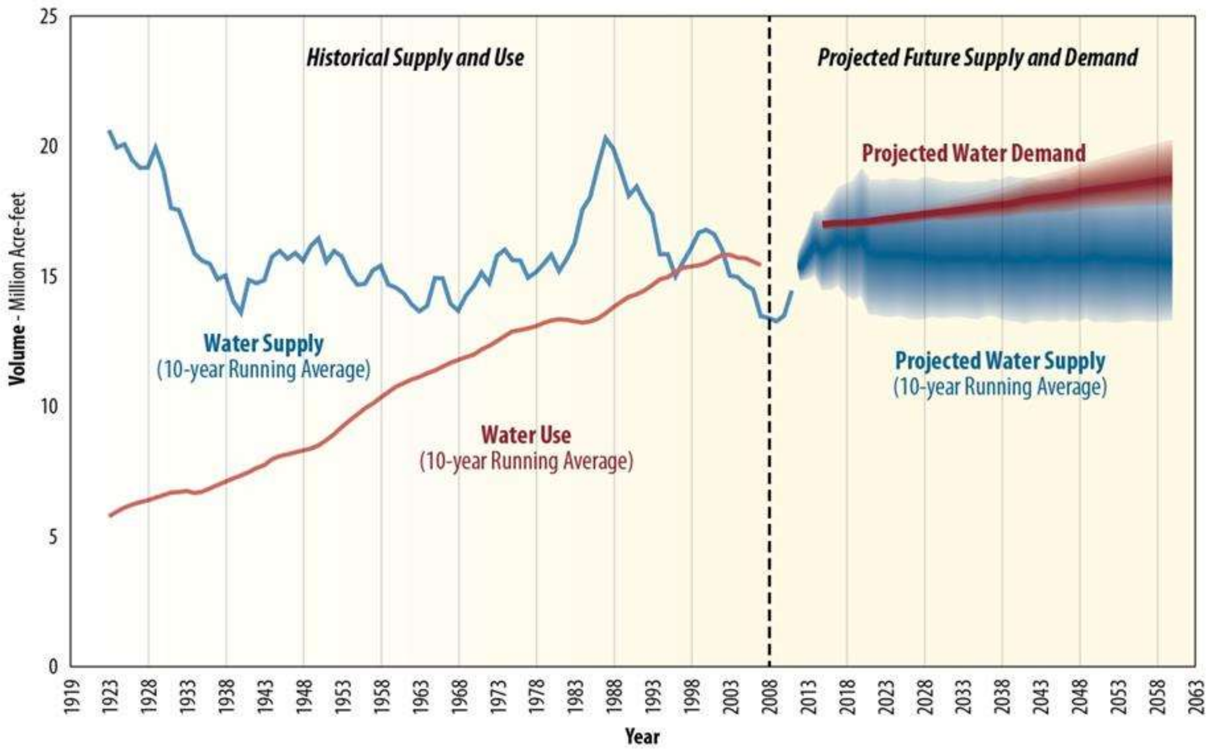


**Figure 3–2. Historical water supply and use plus projected future water supply and demand in the Colorado River Basin.[9]**

**Source: Reclamation, 2012 (CO Basin Study Executive Summary), Figure 2.**
**Note: A range of future water supply and demand projections are presented (dashed blue and red lines) as well as the average future supply and demand projections (solid lines).**

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[8] Comparing the 90th percentile supply to the 10th percentile demand results in no imbalance. Comparing the 10th percentile supply to the 90th percentile demand results in a 6.8-MAF imbalance. Comparing the 50th percentile of both supply and demand results in a 3.2-MAF imbalance.

[9] Water use and demand include Mexico's allotment and losses such as those due to reservoir evaporation, native vegetation, and operational inefficiencies.

No single sector can provide the solution for addressing future uncertain conditions or ensuring long-term sustainability. To respond to the challenges of the future, diligent planning is required to find adaptable solutions that build resiliency and apply a wide variety of ideas at local, state, regional, and basin-wide levels. With this in mind, Reclamation continues to investigate uncertainties related to water use, water-use efficiencies, reuse, and environmental and recreational flows by conducting a deeper analysis of issues and potential solutions identified in the Basin Study. Examples of these efforts include the following:

- **The Colorado River Basin Study *Moving Forward* Effort –** This effort was designed to pursue several areas of the next steps identified in the Basin Study. The *Moving Forward* effort (Reclamation, 2015 [Moving Forward]) builds upon and enhances the broad, inclusive stakeholder process demonstrated in the Basin Study with an ultimate goal of identifying actionable steps to address projected water supply and demand imbalances that have broad-based support and provide a wide range of benefits.
- **West Salt River Valley Basin Study –** The West Salt River Valley, located in central Arizona in the western portion of the Phoenix metropolitan area, is one of the fastest growing areas in Phoenix. Developing renewable water supplies, such as surface water and wastewater, will be important in slowing the existing groundwater overdraft. Funded by Reclamation in 2013, this study is examining and updating water supplies and demands projections, modelling groundwater and potential recharge, developing alternatives to deliver surface water, and identifying climate change adaptation strategies. This study is underway expected to be completed in 2016.
- **Colorado River Basin Ten Tribes Partnership Tribal Water Study –** Begun in late 2013, this study is a collaboration with the Ten Tribes Partnership,[10] whose members hold a significant amount of quantified and unquantified Federal reserved water rights to the Colorado River and its tributaries. The study builds on the technical foundation of the Basin Study by further assessing water supplies and demands for these tribes and identifies tribal opportunities and challenges associated with the development of tribal water. This study is scheduled to be completed in 2016.

## 1.2 Current Drought Conditions

In addition to the long-term challenges identified in the Basin Study, current extended drought conditions in the basin have further heightened a sense of

[10] The tribes involved are: Chemehuevi Indian Tribe, Cocopah Indian Tribe, Colorado River Indian Tribes, Fort Mojave Indian Tribe, Jicarilla Apache Nation, Navajo Nation, Quechan Indian Tribe, Southern Ute Indian Tribe, Ute Indian Tribe of the Uintah and Ouray Reservation, and Ute Mountain Ute Indian Tribe.

urgency for ensuring Colorado River sustainability. The period from 2000 to 2015 was the lowest 16-year period for natural flow in the last century. Paleorecords indicate that this period was also one of the lowest 16-year periods for natural flow in the past 1,200 years (Meko et al., 2007).

During the drought, storage in Colorado River system reservoirs (system storage) has declined from nearly full to about half of capacity. Lake Mead has experienced its lowest elevations since May 1937 during the reservoir's initial filling (Figure 3–3). Despite these dry conditions, Reclamation has been able to meet contracted delivery commitments and scheduled reservoir releases throughout the drought. In the Upper Basin, junior priority water users in subbasins above major Reclamation reservoirs have experienced local shortages throughout the drought. Every resource in the basin is experiencing the impact of these current drought conditions, proving that no one sector solely bears the burden of these challenging conditions.

**Figure 3–3. Lake Mead from Hoover Dam in March 2014.**

## 1.3 Ongoing Efforts to Enhance System Reliability

The challenges and complexities of ensuring a sustainable water supply and meeting future resource[11] needs in an over-allocated and highly variable system such as the Colorado River have been recognized and documented by Reclamation, the Basin States, and many stakeholders. Consequently, significant investments have been made in constructing infrastructure, developing other water resources, and implementing innovative conservation programs and policies to sustain current and future supplies. Notable examples include Hoover and Glen Canyon Dams, the Central Arizona and Central Utah projects, Colorado's many headwaters trans-basin diversions, California's Colorado River Aqueduct, the All-American Canal, and a wide range of other local and regional water infrastructure projects. In the latter part of the 20th century and in the early portion of the 21st century, focus has shifted from developing available water resources to an emphasis on improving the efficiency of the operation of Colorado River reservoirs and better planning and managing of available water supplies. Two notable examples from this period are the Operation of Glen Canyon Dam Final Environmental Impact Statement (Reclamation, 1996) and the Colorado River Interim Guidelines for Lower Basin Shortages and Coordinated Operations of Lake Powell and Lake Mead Final Environmental Impact Statement (Interim Guidelines [Reclamation, 2007]). Both of these resulted in the adoption of new reservoir operating policies. These efforts have resulted in solutions to past water management challenges and will continue to provide benefits in meeting the challenges that lie ahead.

Future challenges arise from the likelihood of continued population growth and the significant uncertainty regarding an adequate future water supply. Nevada, Arizona, and Utah rank first, second, and third, respectively, for the greatest population growth rates in the United States from 2000 to 2010. During that same decade, California experienced the second-greatest population increase in the United States (U.S. Census Bureau, 2011). Along the Colorado Front Range, emphasis on water conservation education programs has contributed to reductions in residential per capita use. The historical population, total M&I water use, and gross per capita water use for the Front Range metropolitan area are shown in Figure 3–4.

All of the major metropolitan areas dependent on Colorado River water are taking action to help ensure sustainable supplies. The communities and economies of major cities such as Albuquerque, Denver, Los Angeles, Phoenix, Salt Lake City, and San Diego are in part dependent, and Las Vegas is almost entirely dependent, on the Colorado River for water supply. As water demand for municipal and

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[11] Resources include water allocations and deliveries for municipal, industrial, and agricultural use; 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.

agricultural purposes increases to serve the needs of growing populations, ensuring the availability of water for non-consumptive uses such as the environment, recreation, and hydropower becomes increasingly challenging, especially since water supply uncertainty is further compounded by the potential impacts from climate change.

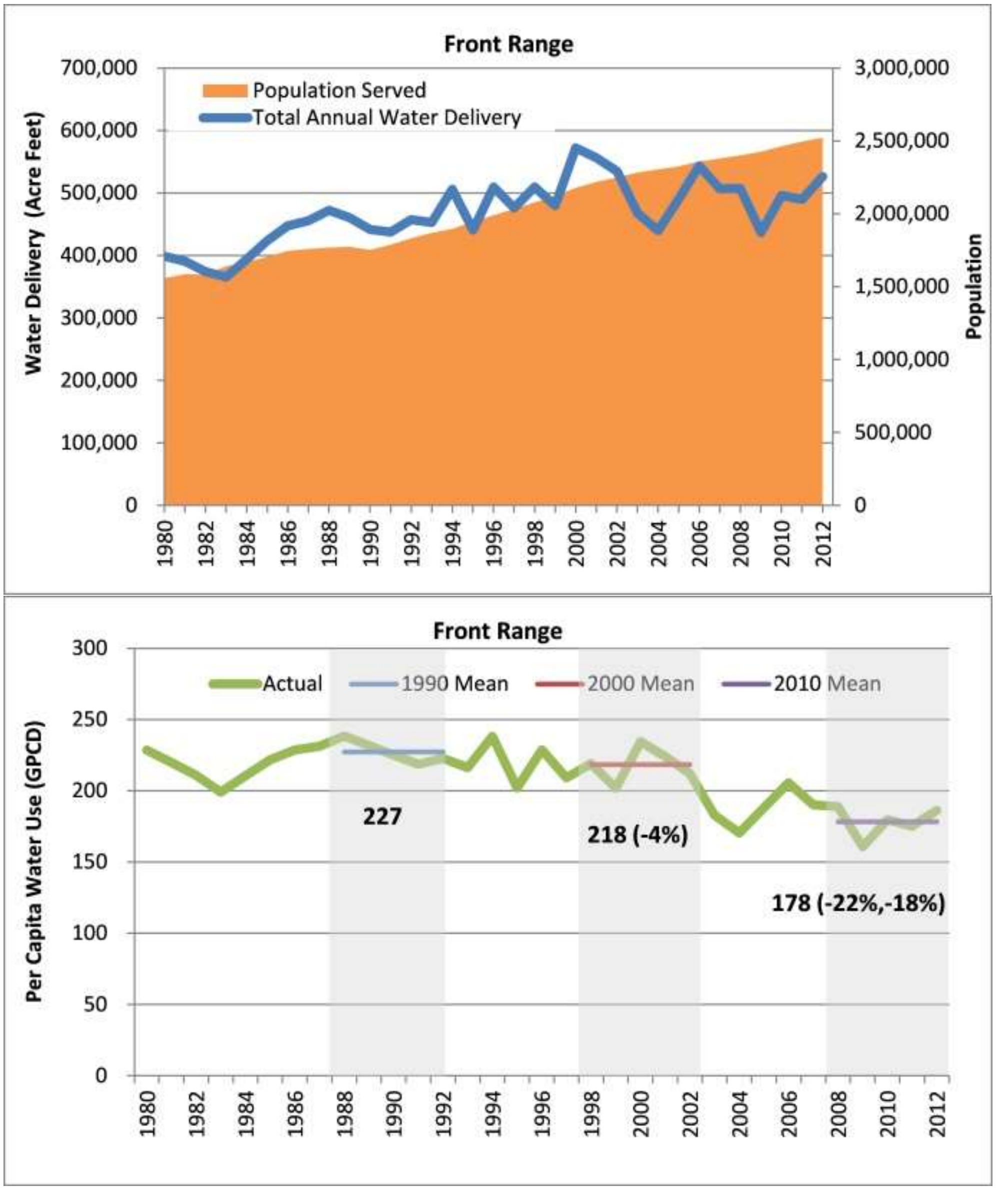


**Figure 3–4. The rising population in the Colorado Front Range metropolitan area has resulted in increased water deliveries over the last three decades, even though per capita use has declined during this period.**
**From: Reclamation, 2015 (Moving Forward), Figure 3-4.**
**Note: As shown on the top graph, the Colorado Front Range metropolitan area has added nearly 1 million people to the municipal water service population since 1980, an increase of approximately 60 percent, while over the same period, the total annual water delivered increased by only about 26 percent.**

# 2 Analysis of Impacts to Water Resources

The Basin Study evaluated the reliability of the Colorado River system to meet basin resource needs under all future supply and demand scenarios (termed baseline system reliability) and defined vulnerable conditions—those stressing to basin resources. Two important vulnerabilities that provide an overall indication of system reliability were:

1. **Lake Mead elevation** dropping below 1,000 feet above mean sea level (msl) in any month and
2. **Lee Ferry deficit,**[12] when the 10-year running total flow at Lee Ferry, Arizona, is less than 75 MAF.

Vulnerability or resource risks in the basin were related to both projected impacts to basin water supply and water demand. Key findings related to projected changes in temperature, precipitation, snowpack, and runoff through 2060 are presented below.[13]

- **Temperature** is projected to increase across the basin, with the largest changes in spring and summer and with larger changes in the Upper Basin than in the Lower Basin.
- **Precipitation** patterns continue to be spatially and temporally complex, but projected seasonal trends toward drying are significant in certain regions. A general trend basin-wide is toward drying, although increases in precipitation are projected for some higher elevation and hydrologically productive regions. Consistent and expansive drying conditions are projected for the spring throughout the basin. For much of the basin, drying conditions are also projected in the summer, although slight increases in precipitation are projected for some areas of the Lower Basin, which may be attributed to the monsoonal influence in this region. Fall and winter precipitation is projected to increase in the Upper Basin but to decrease in the Lower Basin.

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[12] Article III(d) of the Colorado River Compact states that the Upper Division States will not cause the flow of the river at the Lee Ferry Compact Point to be depleted below an aggregate of 75 maf for any period of 10 consecutive years. For the purpose of the Basin Study, a Lee Ferry deficit is defined as the difference between 75 MAF and the 10-year total flow arriving at Lee Ferry.

[13] These findings are based on the assessment described in the Colorado River Basin Water Supply and Demand Study, Technical Report B – Water Supply Assessment (Reclamation, 2012 (CO Basin Study TR-B). Additionally, Chapter 2: West-wide Climate Assessment Summary Report of the SECURE Report to Congress provides the latest Reclamation climate projections for the Colorado River Basin.

- **Snowpack** is projected to decrease as more precipitation falls as rain rather than snow, and warmer temperatures cause an earlier melt. Even in areas where precipitation increases or does not change, decreased snowpack is projected in the fall and early winter as warming temperatures result in more rain and less snow. Substantial decreases in spring snowpack are projected to be widespread, due to earlier melt or sublimation of snowpack.
- **Runoff** (both direct and baseflow) is spatially diverse, but is generally projected to decrease, except in the northern Rockies. As with precipitation, runoff is projected to increase significantly in the higher elevation Upper Basin during winter, but is projected to decrease during spring and summer.
- **Droughts**[14] lasting 5 or more years are projected to occur 50 percent of the time over the next 50 years.

The Basin Study also considered a range of projections based on data and information provided by the Basin States, tribes, Federal agencies, and other water entitlement holders. Key findings related to projected changes in demand are summarized below.

- Under the scenarios considered by the Colorado River Basin Study, the demand for consumptive uses was projected to range between about 18.1 MAF to 20.4 MAF by 2060. The largest increase in demand is projected to be in the M&I category, owing to population growth.
- Future water demands may be affected by a changing climate, primarily due to changes in ambient temperature and the amount and distribution of precipitation. The mean projected change in evapotranspirative demand was approximately 4 percent by 2060, compared to demands without changes in climate. A total demand increase of more than 500 TAF per year by 2060 was estimated, considering potential effects of climate change (Reclamation, 2012 [CO Basin Study TR-C]).

In the Basin Study, impacts to water resources or system reliability were modeled considering all combinations of the projected supply and demand scenarios. Additionally, two operational assumptions were considered regarding Lake Powell and Lake Mead operations beyond 2026 (the end of effective period of the Interim Guidelines (Reclamation, 2007). Additionally, despite findings that the Lower Division States have demand for Colorado River water beyond their 7.5 MAF basic apportionment, the baseline system reliability assumed deliveries to the Lower Division States remain consistent with their basic apportionment. Since each supply scenario had more than 100 individual sequences, the baseline system reliability comprised more than 20,000 simulations. The Baseline system reliability revealed that many combinations of future water supply and demand result in management challenges (Figure 3–5).

[14] For the purpose of the Basin Study, a drought period occurs whenever the running 2-year average flow at Lees Ferry falls below 15.0 M, the observed historical long-term mean.

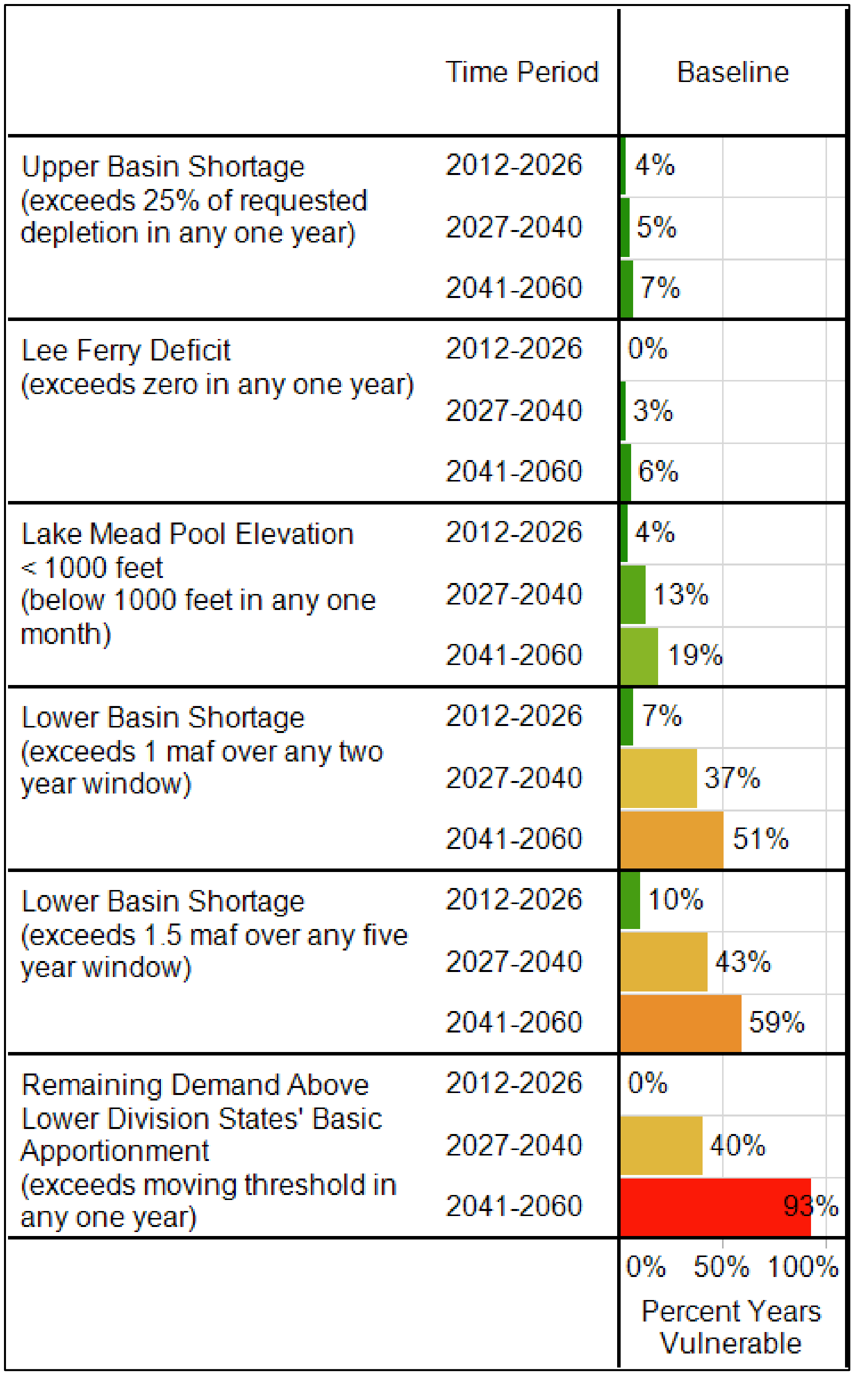


**Figure 3–5. Percent of vulnerable years for each water delivery indicator metric across three time periods for the baseline.**

**Modified from: Reclamation, 2012 (CO Basin Study), Figure 22.**
**Note: green depicts vulnerabilities less than 25 percent; yellow depicts vulnerabilities between 25 to 50 percent; orange depicts vulnerabilities between 50 to 75 percent; red depicts vulnerabilities between 75 to 100 percent.**
**Note: The percentage of vulnerable years for water deliveries increases in intensity through the downstream storage reservoirs and over future projected time periods.**

In the near-term (2012 through 2026), water demands are similar across scenarios, and the largest factor affecting the system reliability is water supply. In the mid-term (2027 through 2040), the demand for water is an increasingly important element in the reliability of the system, as are assumptions regarding the operations of Lakes Powell and Mead. In the long-term (2041 through 2060), the futures that consider the Downscaled GCM Projected water supply scenario, which incorporates projections of future climate, show a high inability to meet resource needs, regardless of the demand scenario and the operation of Lakes Powell and Mead.

In summary, the baseline analysis indicated that without action, it would become increasingly difficult for the system to meet basin resource needs over the next 50 years. For instance:

- Future projected development of water supplies and increased consumptive use in the Upper Basin combined with potential reductions in future supply results in reduced volumes of water stored in system reservoirs.
- With lower water elevations in reservoirs, the needs for resources such as hydropower and shoreline recreation were less frequently satisfied, while water delivery shortages increased.
- Decreases in flows in key river tributaries have negative implications for flow-dependent resources such as recreation and river ecology.
- Flood-control vulnerabilities were few and actually decreased over time under the baseline condition due to the increase in availability of storage associated with growing demand.

These findings fully support the need to develop and evaluate options and strategies to help resolve the water supply and demand imbalance.

# 3 Potential Adaptation Strategies to Address Vulnerabilities

In the Colorado River Basin Study and the *Moving Forward* Effort, the Federal government, Basin States, and basin stakeholders recognize that no single option will be sufficient to resolve future projected supply and demand imbalances. In the Colorado River Basin Study groups of options, or portfolios, were developed for analysis purposes. The objective of the portfolio analyses in this Basin Study was to demonstrate the effectiveness of different strategies in resolving future supply and demand imbalances.

## 3.1 Colorado River Basin Study Potential Future Climate Adaptation Actions

To identify a broad range of additional potential options to resolve water supply and demand imbalances, input was sought from Basin Study participants, interested stakeholders, and the public; more than 150 suggestions were received. Although several of the ideas may ultimately be considered too costly or technically infeasible, the Basin Study explored the wide range of options with the goal of ensuring that all viable options were considered. Each submitted option was assigned to a category based on its primary function. Recognizing that time and resource constraints would not allow for full evaluation of every option, about 30 representative options that spanned the range of the option categories were developed. A summary of the representative options, yield, and timing, where applicable, is provided in Table 3–1.

Although the portfolios explored in the Basin Study addressed water supply and demand imbalances differently, there were commonalities across the options implemented for each portfolio. All of the portfolios incorporate significant agricultural water conservation, M&I water conservation, energy water-use efficiency, and some levels of weather modification. However, some options were implemented more frequently in response to challenging water supply conditions. For example, ocean and brackish water desalination, wastewater reuse, and importation options were implemented for the most challenging water supply conditions in portfolios in which they were included. Future planning requires careful consideration of the timing, location, and magnitude of anticipated future Basin resource needs.

**Table 3–1. Summary of Options and Potential Yields by 2035 and 2060**

Modified from: Colorado River Basin Water Supply and Demand Study, Executive Summary, Table 2

| Option Category | Representative Option | Years Before Available | Potential Yield by 2035 (AFY) | Potential Yield by 2060 (AFY) |
|---|---|---|---|---|
| Desalination | Gulf of California | 20–30 | 200,000 | 1,200,000 |
| | Pacific Ocean in California | 20–25 | 200,000 | 600,000 |
| | Pacific Ocean in Mexico | 15 | 56,000 | 56,000 |
| | Salton Sea Drainwater | 15–25 | 200,000 | 500,000 |
| | Groundwater in Southern California | 10 | 20,000 | 20,000 |
| | Groundwater in the Area near Yuma, Arizona | 10 | 100,000 | 100,000 |
| | **Subtotal** | | 776,000 | **2,476,000** |
| Reuse | Municipal Wastewater | 10–35 | 200,000 | 932,000 |
| | Grey Water | 10 | 178,000 | 178,000 |
| | Industrial Wastewater | 10 | 40,000 | 40,000 |
| | **Subtotal** | | 418,000 | **1,150,000** |
| Local Supply | Treatment of Coal Bed Methane-Produced Water | 10 | 100,000 | 100,000 |
| | Rainwater Harvesting | 5 | 75,000 | 75,000 |
| | **Subtotal** | | 175,000 | **175,000** |
| Watershed Management | Brush Control | 15 | 50,000 | 50,000 |
| | Dust Control | 15–25 | 280,000 | 400,000 |
| | Forest Management | 20–30 | 200,000 | 300,000 |
| | Tamarisk Control | 15 | 30,000 | 30,000 |
| | Weather Modification | 5–45 | 700,000 | 1,700,000 |
| | **Subtotal** | | **1,260,000** | **2,480,000** |
| Importation | Imports to the Colorado Front Range from the Missouri or Mississippi Rivers | 30 | 0 | 600,000 |
| | Imports to the Green River from the Bear, Snake[1], or Yellowstone Rivers | 15 | 158,000 | 158,000 |
| | Imports to Southern California via Icebergs, Waterbags, Tankers, or from the Columbia River[1] | 15 | 600,000 | 600,000 |
| | **Subtotal** | | **758,000** | **1,358,000** |

| Option Category | Representative Option | Years Before Available | Potential Yield by 2035 (AFY) | Potential Yield by 2060 (AFY) |
|---|---|---|---|---|
| M&I Water Conservation | M&I Water Conservation | 5–40 | 600,000 | 1,000,000 |
| | **Subtotal** | | **600,000** | **1,000,000** |
| Agricultural Water Conservation | Agricultural Water Conservation | 10–15 | 1,000,000 | 1,000,000 |
| | Agricultural Water Conservation with Transfers | 5–15 | 1,000,000 | 1,000,000 |
| | **Subtotal** | | **1,000,000** [2] | **1,000,000** [2] |
| Energy Water Use Efficiency | Power Plant Conversion to Air Cooling | 10 | 160,000 | 160,000 |
| | **Subtotal** | | **160,000** | **160,000** |
| System Operations | Evaporation Control via Canal Covers | 10 | 18,000 | 18,000 |
| | Evaporation Control via Reservoir Covers | 18 | 200,000 | 200,000 |
| | Evaporation Control via Chemical Covers on Canals and Reservoirs | 15–25 | 200,000 | 850,000 |
| | Modified Reservoir Operations | 15 | 0 – 300,000 | 0 – 300,000 |
| | Construction of New Storage | 15 | 20,000 | 20,000 |
| | **Subtotal** | | **588,000** [3] | **1,238,000** [3] |
| | **Total of All Options** | | **5,735,000** [4] | **11,037,000** [4] |

AFY = acre-feet per year

[1] Among the more than 150 options received by Reclamation and deemed responsive to the *Plan of Study*, additional importation of water supplies from various sources, including from the Snake and Columbia River systems, were submitted.  Such options were appropriately reflected in the Basin Study but did not undergo additional analysis as part of a regional or river basin plan or any plan for a specific Federal water resource project.

[2] The two agricultural water conservation representative options derive potential yield from similar measures and are thus not additive.

[3] Subtotal assumes 150,000 AFY for the Modified Reservoir Operations representative option.

Note that the potential adaptation strategies listed in the table are organized by category.  Total does not account for several options that may be mutually exclusive due to regional integration limitations or are dependent on the same supply.

## 3.2 Current and Planned Adaptation Actions

The Federal government, Basin States, and basin stakeholders have made significant investments in developing infrastructure, identifying water resources and implementing programs and policies to balance current and future supplies with existing and future demands.  Many of these efforts have resulted in solutions to past water management challenges and will continue to provide benefit to the system in meeting the challenges that lie ahead. Actions to improve the sustainability of the Colorado River are occurring at a variety of scales and locations, ranging from basin-wide initiatives to specific infrastructure improvements. Examples of some of the activities occurring throughout the basin in which Reclamation is involved are described below.

## Planning Activities and Pilot Programs

*Colorado River Basin Ten Tribes Partnership Tribal Water Study* – The tribes of the Ten Tribes Partnership hold a significant amount of quantified Federal reserved water rights to the Colorado River and its tributaries, and in addition, some tribes have unresolved reserved rights claims. In recognition of the importance in bringing the tribal perspective to bear in furthering the understanding and management of Colorado River water, Reclamation and the members of the Ten Tribes Partnership began this Study in 2014. The purpose of the Study is to, for the tribes of the Partnership,[15] assess tribal water supplies, document current tribal water use, project future water demand, document use of tribal water by others, and identify tribal opportunities and challenges associated with the development of tribal water considering the future projected water supply and demand imbalances documented in the Basin Study.

*Drought Contingency Planning*: Reclamation and the Colorado River Basin states are concerned with the potential that critically low elevations in Lake Powell and Lake Mead would be reached if the ongoing drought continues. Work is ongoing in both basins to develop and pursue strategies to avoid reaching such elevations, should this drought continue.

Strategies currently being considered in the Upper Basin include:

- Steps to manage demand by upper basin stakeholders to allow more water to reach Lake Powell;
- Extended and coordinated operations of Colorado River Storage Project reservoirs to better maintain the power pool at Glen Canyon Dam; and
- The potential for increased weather modification, including support from Reclamation, in the Upper Basin.

In the Lower Basin, Reclamation is working with Arizona, California, and Nevada to identify proactive steps to lower the risk of reaching critical elevations at Lake Mead. A step forward was a Memorandum of Understanding (MOU) for Pilot Drought Response Actions, signed by Reclamation and several water agencies in the lower Basin States in December 2014. The MOU outlines a commitment by the parties to use best efforts to generate between 1.5 and 3.0 MAF of additional water in Lake Mead through 2019.

[15] For purposes of the Study, "tribal" refers collectively to the tribes and only those tribes of the Ten Tribes Partnership.

*System Conservation Pilot Program* – In July 2014, an $11 million funding agreement for system conservation was executed among Reclamation, the Central Arizona Water Conservation District, the Metropolitan Water District of Southern California, Denver Water, and the Southern Nevada Water Authority. The Pilot System Conservation Program (PSCP) allows water users to participate in pilot projects that establish temporary, voluntary, compensated programs to conserve or reduce the use of Colorado River water, increasing storage levels in Lake Powell and Lake Mead for the benefit of the Colorado River system. Requests for proposals under the PSCP have been received by potential program participants in both the upper and Lower Basins, and implementation agreements were executed in 2015.

*Reservoir Operations Pilots* – In the Upper Colorado Region, Reservoir Operations Pilot efforts have primarily focused on evaluating past flow trends (e.g., earlier runoff, lower overall inflow, etc.) and how those have or could affect reservoir operations and whether reservoir operations have already adapted to changing climate or will need to adapt in the future.

## Operational Flexibility - 2007 Interim Guidelines

In response to 7 years of unprecedented drought in the basin, the Colorado River 2007 Interim Guidelines (Reclamation, 2007) were adopted by the Secretary of the Interior in December 2007 in consultation with the seven Basin States and stakeholders. The Interim Guidelines, in effect for an interim period through 2026, provide a prescriptive methodology for determining the annual releases from Lake Powell and Lake Mead throughout the full range of reservoir operations, including periods of low reservoir levels.

The Interim Guidelines also provide criteria for determining and implementing shortage reductions in the Lower Basin and a mechanism for Lower Basin water contractors to conserve and store water in Lake Mead as Intentionally Created Surplus (ICS). At the end of calendar year 2014, there was approximately 837 TAF of ICS in storage, equivalent to about 10 feet in Lake Mead at current elevations. The Interim Guidelines do not include provisions for Mexico.

## Municipal and Industrial Water Conservation

Through the WaterSMART program, Reclamation provides leadership and technical assistance focusing on water conservation and helping water and resource managers make wise decisions about water use. In the basin, Reclamation funds metering programs, residential indoor and outdoor conservation, commercial, industrial and institutional conservation, and water reuse.

For example, in 2010, Reclamation collaborated with the Weber Basin Water Conservancy District to install 1,100 water meters on untreated irrigation systems in central Utah. These meters are estimated to save an average of 0.25 acre-feet of water per year and overall are proving to be an effective way in helping consumers understand how much water they are using and how to appropriately adjust usage. In southern California, WaterSMART Grants have been used by municipal water agencies to provide rebates for turf replacement, installation of advanced meters for residential and commercial customers, and construction of recharge basins to develop groundwater storage, among other types of projects.

## Agricultural Water Conservation

Reclamation supports a variety of programs that offer conservation and efficiency project funding. Projects funded through WaterSMART Grants in the Colorado River Basin include conversion of unlined irrigation canals to buried pipe and installation of advanced flow meters, automated valves, and gates to increase efficiency. Through the Colorado River Basin Salinity Control Program, Reclamation has collaborated with the National Resources Conservation Service (NRCS) and the Basin States to provide cost-share assistance to landowners who install salinity control measures. These projects typically involve off-farm conveyance work and on-farm efficiency measures to reduce deep percolation, which mobilize and transport salts back to the river system (Figure 3–6).

**Figure 3–6. Low-pressure sprinkler irrigation.**

In June 2014, the Basin was named a Critical Conservation Area under the NRCS Regional Conservation Partnership Program (RCPP), allowing project proponents to compete for an additional pool of RCPP funds. NRCS has collaborated with Reclamation and the Colorado River Water Conservation District to implement a large agricultural water efficiency project on the Gunnison River. The grant will help irrigators use water more efficiently and reduce the amount of salts and selenium carried in the Colorado River and its tributaries. These efforts include boosting water efficiency by coordinating canals, ditches and pipes that deliver water to farms with improvements in the way water is delivered to crops, frequently by eliminating flood irrigation in favor of sprinkler and other irrigation systems.

## Environmental and Recreational Flows

Reclamation participates as a partner in many new and existing programs established for protecting or improving ecological and recreational opportunities on the Colorado River and its tributaries. Reclamation activities include providing project funding, cost share funding with managing partners, coordinating reservoir operations, collaborating on species recovery and habitat conservation programs, and participating in stakeholder and interagency workgroups. Some examples of these activities follow.

Signed in November 2012, Minute 319 is a historic binational agreement that promotes sharing, conserving, and storing Colorado River water. Minute 319 provides, in part, water for environmental flows for the Colorado River Delta, and an opportunity to gain important scientific information on the effectiveness of these flows. From March through May 2014, a one-time pulse flow event of approximately 105,000 acre-feet was released to the riparian corridor of the Colorado River Delta from Morelos Dam at the U.S.-Mexico border. The water flowed down the river's channel, infiltrated to groundwater and helped to regenerate native cottonwood and willow habitat. A portion of the water eventually flowed to the Gulf of California. The experimental flow provided the scientific community the opportunity to gather valuable data from collaborative monitoring activities; these data will inform both countries in developing future management actions regarding water flows in the delta.

The construction and operation of dams on the Colorado River have fundamentally altered the Colorado River ecosystem. Because of the importance of the Colorado River to the desert Southwest, there is considerable debate over how to share and manage this natural resource. An important part of that debate is the need to address the impacts to the downstream ecosystem resulting from the ongoing operation of Reclamation dams in the Colorado River. To address this challenge at Glen Canyon Dam, Reclamation is a partner in the Glen Canyon Dam Adaptive Management Program, established in 1997, to provide for long-term research and monitoring of downstream resources. The scientific information obtained under the Adaptive Management Program is used as the basis for recommendations for dam operations and management actions. Through the adaptive management approach, scientific experimentation is integrated into resource management actions.

For example, Reclamation and the National Park Service are preparing an environmental impact statement (EIS) for the adoption of a long-term experimental and management plan for the operation of Glen Canyon Dam. The EIS will fully evaluate dam operations and will provide the basis for decision that identify management action and experimental options that will provide a framework for adaptively managing Glen Canyon Dam over the next 15 to 20 years.

Other examples of environmental and recreational flow activities in the Colorado Basin include the Upper Colorado River Endangered Fish Recovery Program, San Juan River Basin Recovery Implementation Program, and the Lower Colorado River Multi-Species Conservation Program.

### Hoover Dam Infrastructure

In cooperation with the Hoover power contractors, Reclamation has begun replacing five of the 17 existing power generating turbines with wide-head turbines at Hoover Dam (Figure 3–7). As the elevation of Lake Mead has dropped in recent years, the ability for water in the reservoir to drive the existing turbines has decreased, and their effectiveness at producing hydroelectric power has been reduced. At current Lake Mead elevations, the water level is at or below the level designed for the existing turbines. The new wide-head turbines can operate at a much wider range of reservoir levels and will allow the Hoover Powerplant to generate electricity more efficiently at lower Lake Mead levels. Four of the new turbines have already been installed and the remaining turbine is scheduled to be installed in Fiscal Year 2017.

### Data and Tool Development

Reclamation continually works to enhance its suite of modeling tools, including the basin's long-term planning model and data to support such tools. Recently, The Nature Conservancy completed a project, funded by the Southern Rockies Landscape Conservation Cooperative (LCC) that explored modeling improvements to represent environmental and recreational flow needs in the planning model more accurately (Alexander et al., 2013). The University of Arizona, funded by the Desert LCC, is completing a geospatial database of environmental flow needs and responses (environmental water demands) to provide water and land managers easy access to the best techniques available for determining how much water ecosystems need. In addition, we are currently analyzing information from the CMIP 5 suite of climate model projections across the Colorado River Basin. This information will be used to conduct additional analysis to update our risk assessments and explore how the new climate projections compare to those used in the Basin Study.

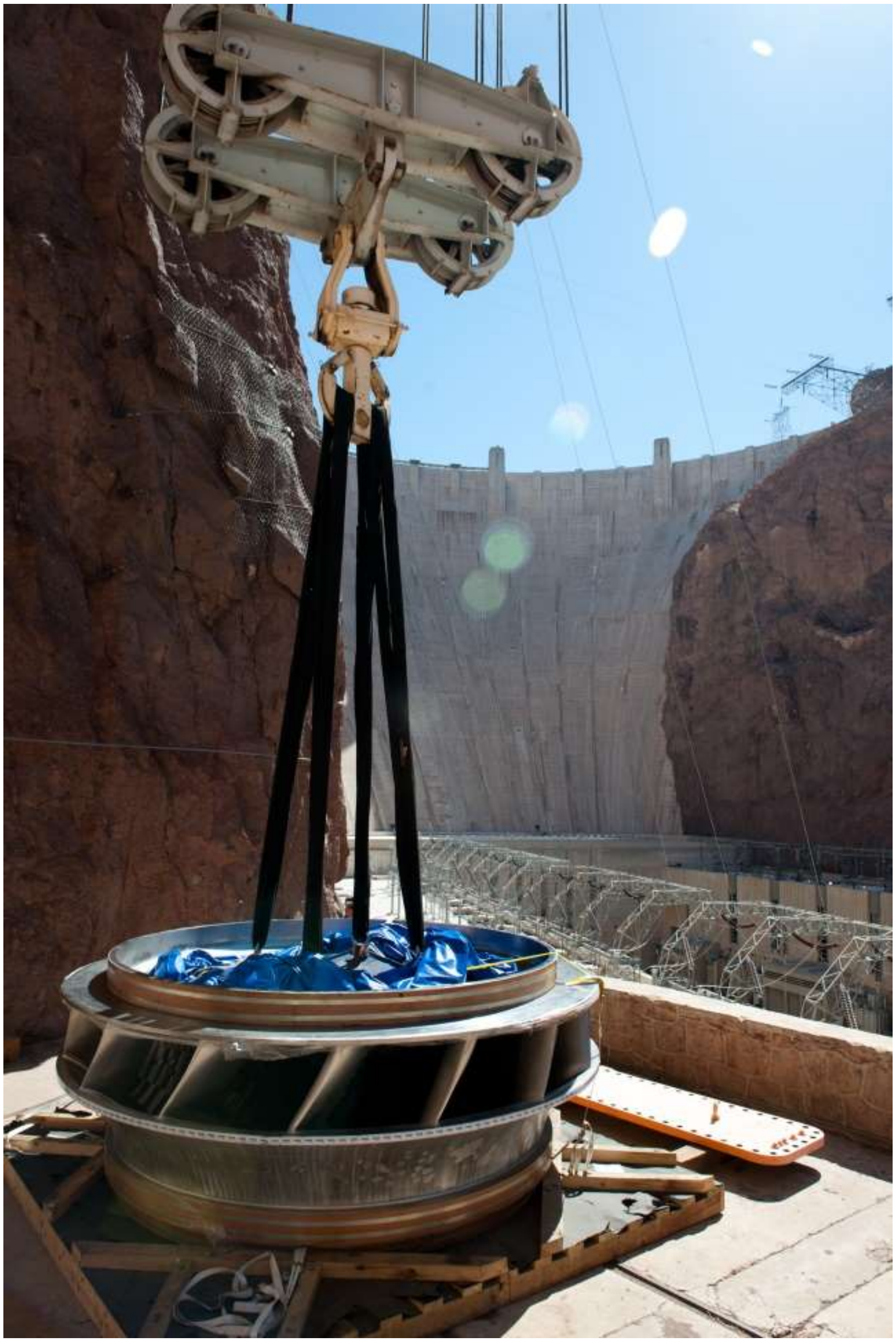

**Figure 3–7. Delivery of a widehead turbine runner for Hoover Dam.**
**The turbine was delivered on a flatbed truck wrapped in a protective tarp. The turbine was flown in using the overhead crane.**
**Date Taken: June 17, 2015.**

# 4 Coordination Activities

Interest in ensuring the sustainability of the Colorado River is broad and includes federal, state, and local governments, tribes, agricultural users, M&I water suppliers, power users, and conservation and recreation groups. No one sector solely bears the burden of future challenging conditions and no one sector can provide the solution for ensuring long-term sustainability. Water management in the basin is complex, as are the challenges associated with balancing competing needs such as water delivery, hydropower generation, and environmental protection. To meet such challenges, various stakeholders have implemented programs and initiatives, each with their own set of goals, objectives, approaches, and processes, in various parts of the basin. These stakeholders recognize that facilitating cross-program coordination and information exchange are important strategies that can allow such programs to work together and focus resources to address basin-wide challenges.

Reclamation and its stakeholders are actively partnering in activities and programs to help mitigate the impact of the on-going drought and to address future water management challenges. These programs include the Pilot System Conservation Program, Drought Contingency Planning efforts, and the Water Conservation Field Services Program. Other examples of precedent-setting partnerships occurring throughout the basin include the Colorado River Basin Ten Tribes Partnership Tribal Water Study and commitments by Reclamation, the Basin States, and Mexico to share and conserve water during both high and low reservoir conditions while also respecting the operational constraints and ecological health of the Colorado River Basin. These activities and programs are described in more detail in section 3.2.

## 4.1 *Moving Forward* Effort

The Basin Study demonstrated that implementing a broad range of options could reduce basin resource vulnerability and improve the basin's resiliency to dry and variable hydrologic conditions. Implementing such options requires diligent planning and collaboration that applies a wide variety of water management ideas throughout the basin.

***Colorado River Basin Study – Moving Forward Effort***: In May 2013, Reclamation and Basin stakeholders initiated the *Moving Forward* effort to build on future considerations and next steps identified in the Colorado River Basin Study. The *Moving Forward* effort enhances the broad, inclusive stakeholder process demonstrated in the Basin Study, with an ultimate goal of identifying actionable steps to address projected water supply and demand imbalances that have broad-based support and provide a wide range of benefits.

The *Moving Forward* effort is being conducted in a phased approach. Phase 1 began with the formation of a coordination team and three multi-stakeholder workgroups that focus on water conservation, reuse, and environmental and recreational flows. The Phase 1 Report was published in May 2015 (Reclamation, 2015 [Moving Forward]). The report documents the activities and outcomes of the workgroups during this phase and includes opportunities for potential future action. Phase 2, which began in 2015, signals the transition from study to action. In this phase, building from the workgroup's identified opportunities for future action; several pilot projects will be identified and pursued.

## 4.2 Additional Coordination

Climate change challenges highlight the need for increased coordination to exchange information, compare findings, and collaborate on data collection and other efforts to establish and address basin-wide priorities. Federal-agency integration within and across Departments is strong throughout the basin. For example, under the WaterSMART program, Reclamation and the U.S. Geological Survey coordinate on a variety of research activities in the basin, including the collection and evaluation of consumptive uses and loss data.

The Southern Rockies and Desert LCCs encompass the basin and are partnerships of governmental (Federal, state, tribal, and local) and non-governmental entities. The primary goal of the LCCs is to bring together science and resource management to inform climate adaptation strategies to address climate change and other stressors within an ecological region, or landscape. There are many examples in the basin of where stakeholder involvement and coordination is a critical element in the success of the program or project such as:

- The Bill Williams River Corridor Steering Committee (BWRCSC) is a stakeholder group that includes regulatory agencies, federal agencies such as Reclamation, non-governmental organizations, local jurisdictions, and scientists with management concerns and responsibilities related to the Bill Williams River (BWRCSC, 2014). This group works cooperatively to help fund and coordinate research and adaptive management of the river's resources.
- On the Upper Colorado River, salinity issues are being addressed by the NRCS, Reclamation, and state agencies through the basin-wide Salinity Control Program, which has implemented irrigation improvements throughout the basin aimed at reducing salt load. Examples of program activities include reducing high salinity agricultural drain water return flows and preventing highly saline waters from reaching the Colorado River.

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