



— BUREAU OF —
RECLAMATION

Colorado River Basin

SECURE Water Act Section 9503(c)

Report to Congress

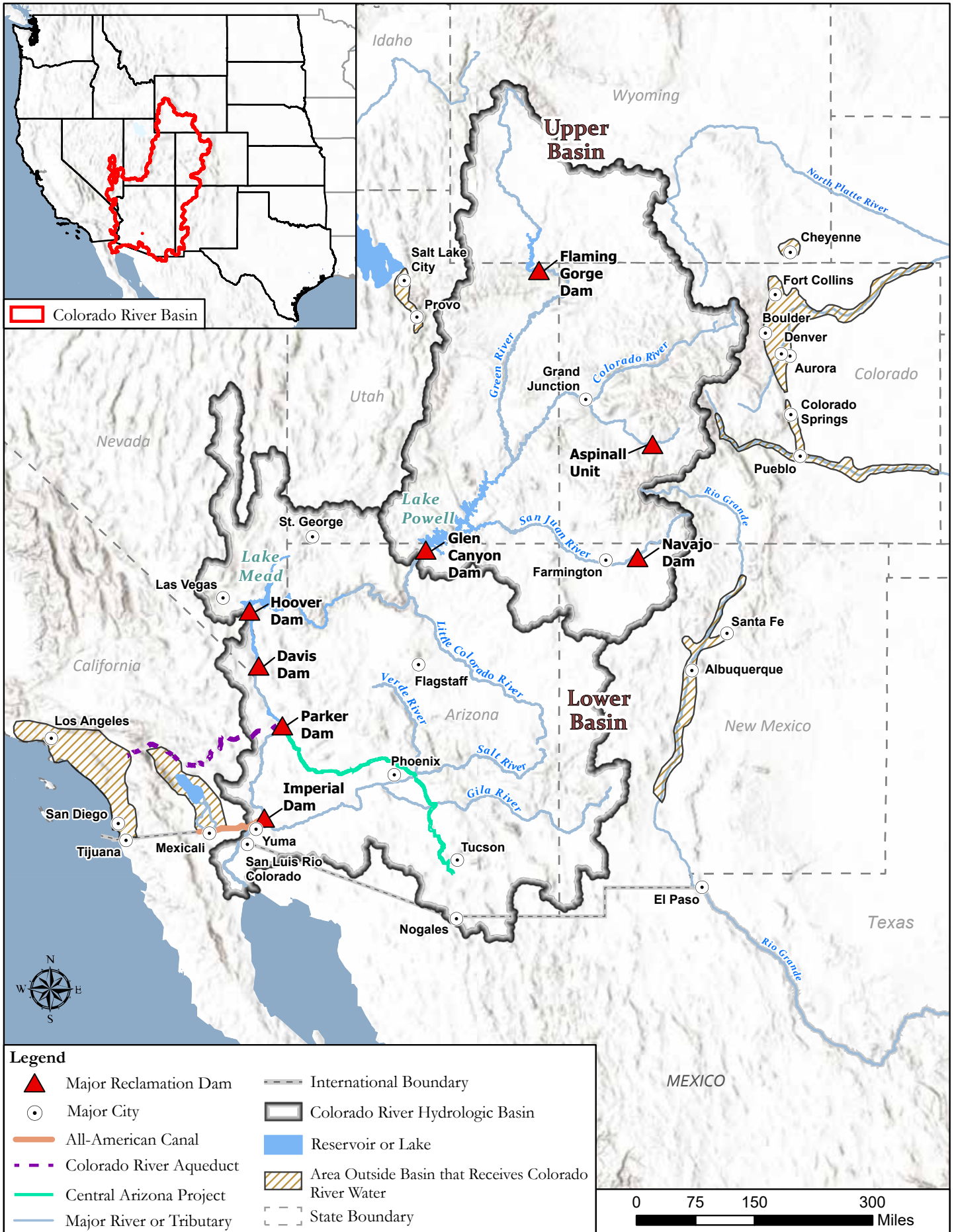
Mission Statements

The Department of the Interior conserves and manages the Nation's natural resources and cultural heritage for the benefit and enjoyment of the American people, provides scientific and other information about natural resources and natural hazards to address societal challenges and create opportunities for the American people, and honors the Nation's trust responsibilities or special commitments to American Indians, Alaska Natives, and affiliated island communities to help them prosper.

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.

Acronyms and Abbreviations

°F	degrees Fahrenheit
2007 Interim Guidelines	<i>Colorado River Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lake Powell and Lake Mead</i>
2007 ROD	2007 Record of Decision implementing the <i>Colorado River Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lake Powell and Lake Mead</i>
Basin	Colorado River Basin
Basin States	Colorado River Basin States (Arizona, California, Colorado, Nevada, New Mexico, Utah, Wyoming)
Basin Study	Colorado River Basin Water Supply and Demand Study
CRB R2O	Colorado River Basin Research-to-Operations Program
DCPs	Drought Contingency Plans
LTEMP	Glen Canyon Dam Long-Term Experimental and Management Plan
MOU	Memorandum of Understanding
Reclamation	Bureau of Reclamation
SECURE Water Act	Science and Engineering to Comprehensively Understand and Responsibly Enhance (SECURE) Water Act
State of the Science Report	Colorado River Basin Climate and Hydrology: State of the Science Report
Tribal Water Study	Colorado River Basin Ten Tribes Partnership Tribal Water Study
Upper Basin States	Colorado, New Mexico, Utah, and Wyoming
USFWS	U.S. Fish and Wildlife Service



Colorado River Basin Setting

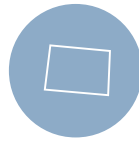
U.S. States



Arizona



California



Colorado



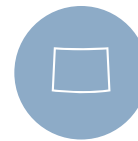
Nevada



New Mexico



Utah



Wyoming

Major U.S. Cities:

- Albuquerque
- Denver

- Las Vegas
- Los Angeles

- Phoenix
- Salt Lake City

- San Diego

Areas Outside the Basin Receiving Colorado River Water:

- Albuquerque and Santa Fe, New Mexico (San Juan Chama Project)
- Cheyenne, Wyoming
- Colorado Front Range (Colorado-Big Thompson and Fryingpan-Arkansas Projects)

- Southern California (Colorado River Aqueduct/All-American Canal)
- Wasatch Front Range (Central Utah Project and Strawberry Valley Project)

International:

Mexico

River Basin Area: 246,000 square miles

River Length: 1,450 miles

Major Water Uses:



Agriculture
(4.5 million acres)



Municipal
(40 million people)



Hydropower
(4,200 megawatts)



Recreation



Fish and Wildlife Habitat






Notable Reclamation Facilities:



- Hoover Dam
- Glen Canyon Dam
- Flaming Gorge Dam
- Aspinall Unit

- Navajo Dam
- Davis Dam
- Parker Dam
- Imperial Dam

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ABOUT

This basin report is part of the 2021 Science and Engineering to Comprehensively Understand and Responsibly Enhance (SECURE) Water Act Report to Congress, prepared by the Bureau of Reclamation in accordance with Section 9503(c) of the SECURE Water Act of 2009, Public Law 111-11. The 2021 SECURE Water Act Report follows and builds upon the first two SECURE Water Act Reports, submitted to Congress in 2011 and 2016. The report characterizes the impacts of warmer temperatures, changes to precipitation and snowpack, and changes to the timing and quantity of streamflow runoff across the West.

The 17 Western States form one of the fastest growing regions in the Nation, with much of the growth occurring in the driest areas. The report provides information to help water managers address risks associated with changes to water supply, quality, and operations; hydropower; groundwater resources; flood control; recreation; and fish, wildlife, and other ecological resources in the West.

To see all documents included in the 2021 SECURE Water Act Report to Congress, go to: <https://www.usbr.gov/climate/secure/>



Crop irrigation in Blythe, California.



SECTION 1

Water Management Challenges

Basin Overview

Today, nearly 40 million people¹ in the seven Colorado River Basin States (Basin States)—Arizona, California, Colorado, Nevada, New Mexico, Utah, and Wyoming—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 (Bureau of Reclamation, 2015) in the Colorado River Basin (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, 29 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 units 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 power 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 country of Mexico.

Total consumptive use and losses in the United States portion of the Basin, including water delivered to Mexico under the 1944 United States-Mexico Water Treaty², have averaged approximately 15.0 million acre-feet³ annually over the past decade (Reclamation, 2015). Federally recognized Tribes have reserved water rights, not including unresolved claims, to approximately 2.5 million acre-feet of annual diversion rights from the Colorado River and its tributaries (Reclamation, 2012 [Water Demand Assessment]). In many cases, these rights are senior in priority to those held by other users.

¹ 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 [Study Report] and Reclamation, 2012 [Water Demand Assessment]).

² The United States-Mexico Treaty on Utilization of Waters of the Colorado and Tijuana Rivers and of the Rio Grande signed February 3, 1944, allocated 1.5 million acre-feet per year to Mexico.

³ Basinwide consumptive use and losses estimated over the period 2002 to 2012, including the 1944 United States-Mexico Water Treaty delivery to Mexico, reservoir evaporation, and other losses due to native vegetation and operational inefficiencies.

Agriculture is the dominant use of Colorado River water, accounting for approximately 70 percent of total Colorado River water used in the United States. Of the total consumptive use, 40 percent is exported outside the Basin's hydrologic boundaries for use in adjacent areas. As shown on the map on page iv, several major metropolitan areas that receive Colorado River water—including Albuquerque and Santa Fe, New Mexico; Denver and Colorado Front Range cities; Salt Lake City, Utah; and Los Angeles and San Diego, California—are located outside the Basin's hydrologic boundaries.

The Colorado River System⁴ is operated in accordance with the Law of the River.⁵ Apportioned water in the Basin, including both the United States and Mexico apportionments, exceeds the average long-term (1906 through 2018) historical natural flow⁶ of about 16.0 million acre-feet (Reclamation, 2020 [Data]). 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 Colorado River System (approximately 60 million acre-feet, 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.

Water Management Complexities

The challenges and complexities of ensuring a sustainable water supply and meeting future resource⁷ needs in an over-allocated and highly variable system such as the Colorado River have been recognized and documented by the Bureau of Reclamation (Reclamation), the Basin States, and many stakeholders. Consequently, significant investments have been made in long-term planning and infrastructure, as well as in implementing innovative programs and policies to sustain current and future supplies.



Flaming Gorge Reservoir.

⁴ The portion of the Colorado River and its tributaries within the United States of America.

⁵ 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. Additional information can be found at: <https://www.usbr.gov/lc/region/g1000/lawofrvr.html>.

⁶ Natural flow represents the flow that would have occurred at the location had depletions and reservoir regulation not been present upstream of that location.

⁷ Resource needs 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.



Releases from Glen Canyon Dam to the Colorado River.

The period from 2000 through 2019 was the driest 20-year period for the Colorado River in more than 100 years of record-keeping and one of the lowest in the last 1,200 years as deduced from tree-ring records. Lake Powell and Lake Mead were nearly full in 1999, providing ample water supplies meeting water demands through this period of historic drought. As of December 2020, the combined storage in Lake Powell and Lake Mead was at 41 percent of capacity.

Challenges also arise from the likelihood of continued population growth and the significant uncertainty regarding an adequate future water supply. Nevada, Arizona, and Utah ranked 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).

Given these challenges and the risks posed by the ongoing historic drought, Reclamation, the Basin States, and Mexico have implemented a

series of actions that work together to reduce the likelihood of Lake Powell and Lake Mead dropping to critically low elevations and helping to ensure the reliability of the Colorado River System. **Figure 1** presents the historical storage volumes of Lake Mead and Lake Powell, as well as recent innovative management actions including:

- The establishment of the *Colorado River Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lake Powell and Lake Mead* (2007 Interim Guidelines) (DOI, 2007) to improve management of the Colorado River water supplies in 2007.
- Binational Colorado River management approaches with Mexico (Minutes 319 and 323 to the 1944 United States-Mexico Water Treaty).
- Drought response actions to avoid reaching critically low elevations at Lake Powell and Lake Mead through 2026 (2019 Drought Contingency Plans).



Sunset on Lake Mead.

In addition to taking proactive management approaches to respond to current and future challenges, diligent planning is necessary to find adaptable solutions that build resiliency and address water supply and demand imbalances at local, State, regional, and Basinwide levels. With this in mind, Reclamation continues to lead and partner with others to investigate uncertainties related to water supply, water use, impacts to related resources, and adaptation measures. These studies range from large-scale, Basinwide efforts to regional and local explorations of water resource conditions.

For example, in 2012, Reclamation, in partnership with the seven Basin States and in collaboration with a wide spectrum of Basin stakeholders, published the most comprehensive study of future Basin water supply and demand ever undertaken. The Colorado River Basin Water Supply and Demand Study (Basin Study) defined current and future imbalances in water supply and demand in the Basin over the next 50 years and developed

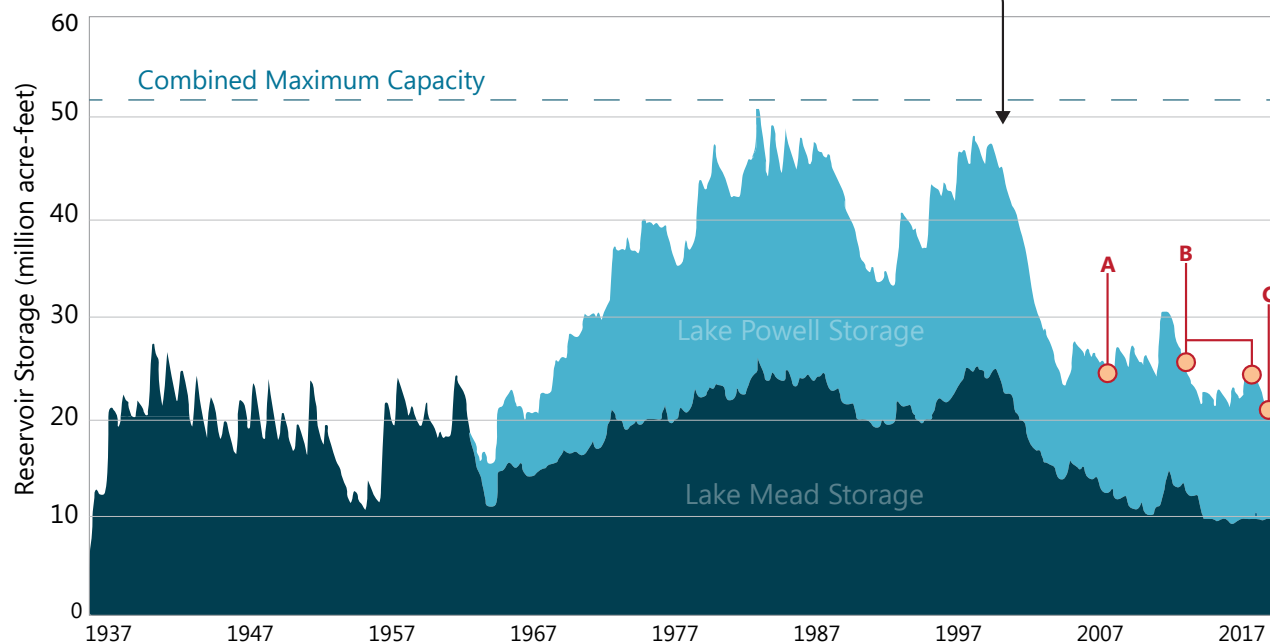
and analyzed options and strategies to resolve those imbalances. The Basin Study confirmed that, in the absence of timely action, there are likely to be significant shortfalls between projected water supplies and demands in the Basin in decades. These shortfalls are likely to affect each sector (for example, agricultural, municipal, industrial, and environmental) dependent on the Colorado River and its tributaries. The Basin Study also confirmed that a wide range of solutions are needed to mitigate and adapt to such shortfalls (Reclamation, 2012 [Study Report]).

Reclamation has used the technical foundation and analysis techniques from the Basin Study as a platform for subsequent studies. These studies, conducted throughout the Basin at a variety of geographic scales, help further the understanding of the complex water supply and demand challenges in the Basin. **Figure 2** presents the Colorado River Basin with the geographic area studied in recent planning efforts.

Water supplies in the Colorado River Basin vary widely from year to year, but the Lake Mead and Lake Powell reservoirs can store nearly 4 times the annual flow.

Fortunately, the Colorado River reservoirs were nearly full at the start of the ongoing drought.

The period from 2000 through 2019 was the driest 20-year period for the Colorado River in more than 100 years of record-keeping.



- A. Colorado River Interim Guidelines for Lower Basin Shortages and Coordinated Operations of Lake Powell and Lake Mead** – The 2007 Interim Guidelines were developed to improve management of Colorado River water supplies; provide water users a greater degree of predictability with respect to annual water deliveries; and provide additional mechanisms for the storage and delivery of water supplies in Lake Mead.
- B. Minutes 319 and 323 to the 1944 United States-Mexico Water Treaty** – Through a binational cooperative process that began in 2007, Reclamation worked in partnership with the Basin States, the International Boundary and Water Commission, and Mexico to develop proactive binational measures to address water conservation, responses to historic drought, and environmental enhancement along the Colorado River in the border region.
- C. 2019 Drought Contingency Plans (DCPs)** – Prior to signing the 2019 DCPs, projections indicated that, without action, the risk of reaching critical elevations at Lake Powell and Lake Mead over the next decade had increased nearly four times. The DCPs are designed to be in place through 2026 and apply drought response actions in addition to those already authorized or required by the 2007 Interim Guidelines.

Figure 1. Lake Powell and Lake Mead Combined Storage

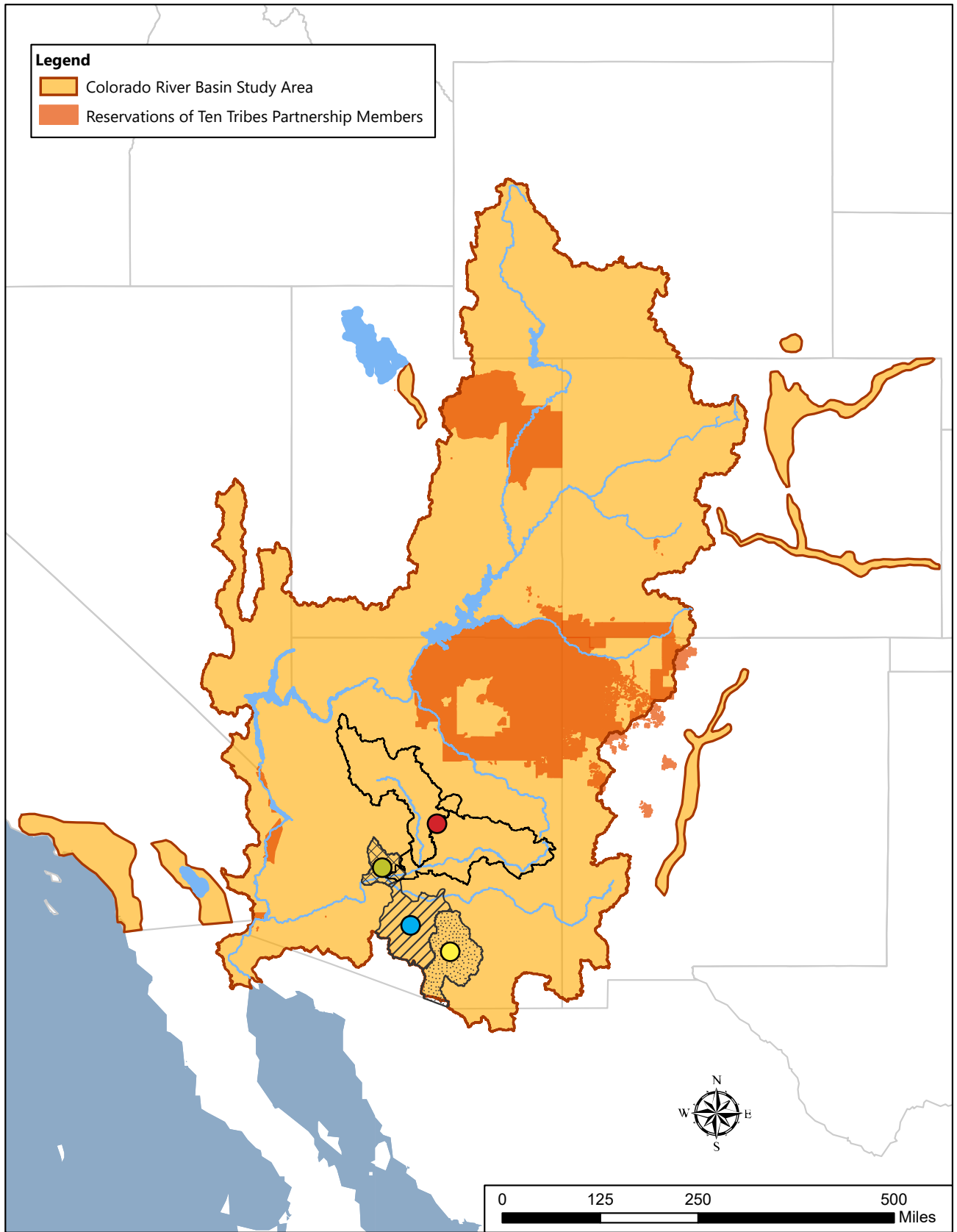


Figure 2. Representative Planning Studies in the Colorado River Basin (see page 7 for descriptions of studies).

● **Colorado River Basin Water Supply and Demand Study (2012)**

The study defined current and future imbalances in water supply and demand in the Basin over the next 50 years. Additionally, it developed and analyzed options and strategies to resolve those imbalances. The Basin Study confirmed that, in the absence of timely action, there are likely to be significant shortfalls between projected water supplies and demands in the Basin in coming decades, and that a wide range of solutions are needed to mitigate and adapt to such shortfalls.

● **Colorado River Basin Ten Tribes Partnership Tribal Water Study (2018)**

The study was a collaboration with the Ten Tribes Partnership⁸ 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.

● **Salt and Verde River Reservoir System Pilot Study (2019)**

The Salt-Verde watershed and their systems of reservoirs supply about 800,000 acre-feet of water annually for multiple uses in the Phoenix metropolitan area. The study concluded that, based on paleohydrology and future climate scenarios, current reservoir operation strategies were sufficient to maintain a secure and reliable water supply to meet the recent levels of demand.

● **West Salt River Valley Basin Study (ongoing)**

The West Salt River Valley is one of the fastest growing areas in the Phoenix, Arizona metropolitan area. The study will include the development of modeling tools and strategies to address current and future imbalances in water supply and demand in the basin.


● **Eloy and Maricopa-Stanfield Basin Study (ongoing)**

Located between the rapidly expanding cities of Phoenix and Tucson, non-tribal agriculture on about 20 percent of the land accounts for about 80 percent of the water use. These agricultural users face large water delivery reductions due to agreements set forth in the 2019 Lower Basin Drought Contingency Plan. To address water supply uncertainties, the study will assess current and future water demands and supplies, and develop strategies to help ensure future water supply sustainability.

● **Lower Santa Cruz River Basin Study (ongoing)**

For over 60 years, residents of the basin relied on groundwater, with pumping greatly exceeding replenishment. The Central Arizona Project began delivering Colorado River water in 1993, but there are still supply-demand imbalances due to a lack of delivery infrastructure and recharge capacity. The study is identifying where water is needed to mitigate imbalances and developing strategies to improve reliability.

⁸The member Tribes of the Ten Tribes Partnership 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.

An aerial photograph of the Hoover Dam, a massive concrete arch dam, situated in a deep desert canyon. The dam is a light tan color and spans across the canyon. Behind the dam, the water of Lake Mead is a vibrant turquoise color, contrasting sharply with the brown and red rock walls of the canyon. The surrounding landscape is rugged and arid, with steep, rocky slopes. In the foreground, a highway bridge with a prominent arch structure crosses over the canyon. The sky is clear and blue.

Summary of Studies in the Colorado River Basin

- Colorado River Basin Climate and Hydrology: State of the Science Study (Lukas and Payton, 2020)
- Colorado River Basin Ten Tribes Partnership Tribal Water Study (DOI et al., 2018)
- Salt and Verde River Reservoir System SECURE Reservoir Operations Pilot Study (Reclamation and Salt River Project, 2019)



SECTION 2

Analysis of Impacts to Water Resources

Since the current drought began in 2000, persistent dry conditions, along with the increasing recognition that warming temperatures are impacting the hydrology of the Basin, have led to great concerns about the long-term reliability of Basin water supplies. For a detailed explanation of climate projections relied on by Reclamation, please refer to Reclamation's 2021 West-Wide Climate and Hydrology Assessment, Section 2.1, and for a discussion of associated uncertainties, please refer to Section 9.1.

State of the Science Report

Reclamation partnered with researchers from the University of Colorado Boulder's Western Water Assessment, other Federal, State, and local water agencies, and leading experts to integrate nearly 800 peer-reviewed studies, agency reports, and other sources to assess the state of the science and the technical methods relevant to water resources in the Basin. The *Colorado River Basin Climate and Hydrology: State of the Science Report* (Lukas and Payton, 2020) aimed to create a shared understanding of the physical setting and the latest data, tools and research underpinning the management of Colorado River water resources.

By synthesizing the most recent research in the Basin regarding climate and hydrology, the State of the Science Report established a broadly shared understanding that can guide the strategic integration of new research into practice. The ultimate goal of that integration is to facilitate more accurate short- and mid-term forecasts, and more meaningful long-term projections, of Basin hydroclimate and system conditions.

Key findings from the State of the Science Report related to projected changes in temperature, precipitation, snowpack, and runoff are presented below:



Temperature

There has been a substantial warming trend over the past 40 years. The period since 2000 has been about 2°F (degrees Fahrenheit) warmer than the 20th century average and is likely warmer than at any time in the past 2,000 years. Over the entire Basin, 2009 to 2018 was the warmest 10-year period on record, and 2017 was the warmest single year. Of the 20 warmest years on record, 17 have occurred since 1994.



Taylor Park Reservoir, Colorado.



Precipitation

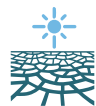
New analyses using Global Climate Models suggest that human-caused climate change is exerting a long-term tendency toward reduced precipitation in the region that includes the Colorado River Basin. However, this tendency is small enough to be overwhelmed by natural variability, and is undetectable from the observed record of precipitation alone (Guo et al., 2019 and Hoerling et al., 2019).



Snowpack and Runoff

Decreases in spring snowpack in many parts of the Upper Basin, as well as decreases in annual Colorado River flows at Lees Ferry, Arizona, have occurred in recent decades. While the timing of peak spring runoff is not as important as the runoff quantity to overall Basin water system outcomes due to the large system storage capacity, some water uses can be sensitive to runoff timing. In particular, direct diversion for irrigation and the variation and trends in the shape of the annual hydrograph can have implications for reservoir operations. Especially for the Upper

Basin, recent studies have detected progressively larger and more pervasive shifts toward earlier spring runoff onset and peak runoff.



Droughts

The period since 2000 has been unusually drought-prone, but several paleodroughts prior to record keeping beginning in 1900 were more severe and sustained than the worst-case droughts since 1900. These “megadroughts” could recur in the future due to natural climate variability alone, but the risk of their recurrence is increased by the recent trend in warming temperatures.

Impacts to Resources

Water is the Southwest’s most precious natural resource. However, water supplies are increasingly stressed by demand from a variety of sources, including a robust agricultural industry, rapid urban growth, and environmental needs. Current and future water supply changes have and are projected to affect resources that depend on Colorado River water. Examples of the effects to Basin resources are described below.

Water Deliveries

To date, there has not been a shortage condition in the Lower Basin, nor a delivery reduction to Mexico. This is due primarily to the ability of Colorado River system reservoirs, particularly Lake Mead and Lake Powell, to hold up to 4 years of average annual inflow, with reservoirs storing water during high flow years and using this water to meet delivery requirements during low flow periods. However, in calendar year 2020, the first water savings contribution was required by Arizona, Nevada, and Mexico, consistent with the Lower Basin Drought Contingency Plan and Minute 323.

The 2018 Tribal Water Study indicated that while the Colorado River System was affected by the Partnership Tribes' development of tribal water, future water supply scenarios had the greatest effect on the system. This was best exhibited with the Global Climate Model supply scenario, which contains more years of reduced supply than the supply scenario based on approximately 100 years of record keeping. When the Colorado River System experienced high levels of water stress, the magnitude of shortages were large enough to minimize the influence of tribal water development.

Hydropower

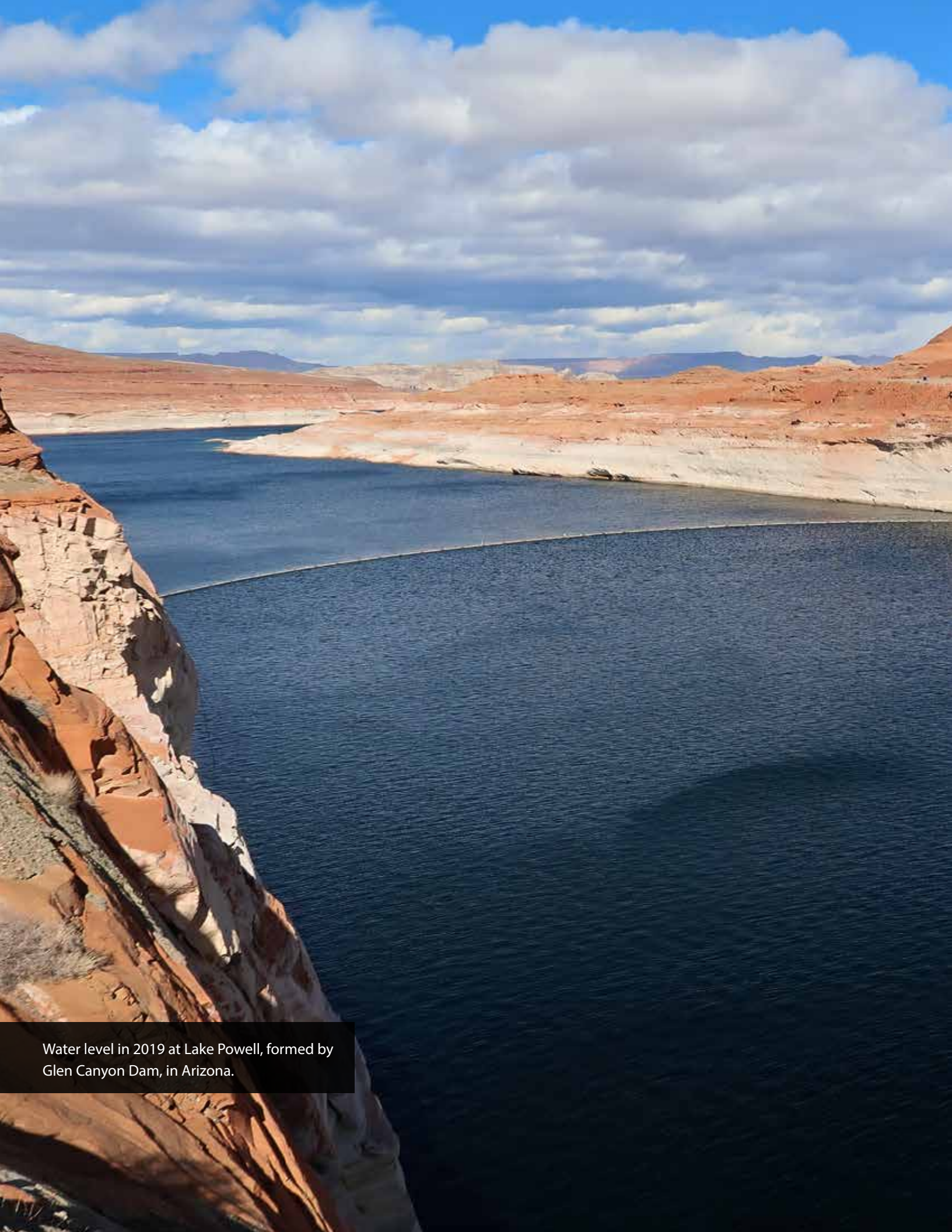
There is a great deal of uncertainty in the effects of the current drought on hydropower. Even with efficiency improvements, impacts to hydropower generation are anticipated to continue. Current projections for hydropower generation at Hoover Dam indicate that there is a relatively high probability of a 0.5 percent to 2.5 percent reduction in hydropower generation from year to year over the next 5 years.



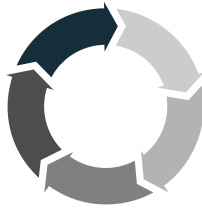
Hydropower generators at Glen Canyon Dam, Arizona.

Reservoir Operations

Reclamation's Reservoir Operations Pilot Studies identify approaches to improve reservoir operations in response to variability in water supplies, floods, and droughts. Reclamation's Lower Colorado Basin Region conducted the Salt and Verde River Reservoir System Reservoir Operations Pilot Study to understand the implications of projected future hydrologic conditions to operations. Highly variable climate conditions experienced in the Salt-Verde watershed over the past century have made it difficult to assess the long-term reliability of water supplies and infrastructure. In particular, recent droughts, such as those from 1999 to 2004 and 2011 to 2016, have caused water managers at the Salt River Project to ask whether their traditional approaches to water management will meet their needs into the future. This study confirmed that the Salt River Project can address any future shortfalls through conservation and the existing system design. These findings can inform other water managers of the importance of looking ahead to identify potential changes in hydrology and incorporating that information into decisions regarding system design and conservation efforts.



Water level in 2019 at Lake Powell, formed by Glen Canyon Dam, in Arizona.



SECTION 3

Potential Adaptation Strategies to Address Vulnerabilities

Through various planning efforts, Reclamation, the Basin States, and Basin stakeholders have come to recognize that no single action or approach will be sufficient to resolve future projected supply and demand imbalances. Strategies are being developed and actions taken to ensure the sustainability of current and future water supplies. Examples of some of the activities occurring throughout the Basin in which Reclamation is involved are described below.

Operational Flexibility

As a result of voluntary water conservation and storage activities by Reclamation, the Basin States, Tribes, and Mexico since 2007, approximately 3 million acre-feet has been conserved in Lake Mead, increasing its elevation by approximately 35 feet (**Figure 3**). This additional water stored and conserved in Lake Mead effectively kept the Lower Basin out of a shortage condition every year since 2016. While these water conservation and storage activities have been successful, Lake Powell and Lake Mead remain at risk of declining to critically low elevations under sustained and severe drought.

Drought Contingency Plans

The Department of the Interior and Reclamation worked collaboratively with partners to develop consensus based DCPs in both the Upper and Lower Basins. When coupled with the 2007 Interim Guidelines and Minute 323, the DCPs executed on May 20, 2019, will ensure a greater likelihood of sustainable operation of the Colorado River System until new operational guidelines can be developed by 2026.

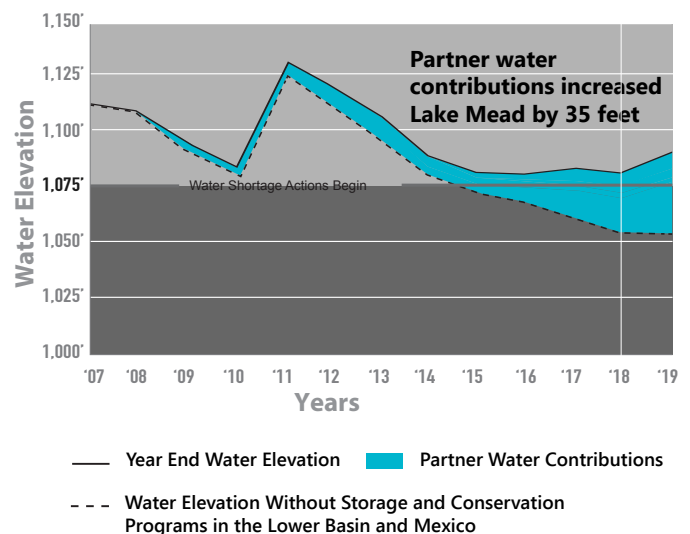


Figure 3. Lake Mead water elevation during the ongoing Colorado River Basin drought.



Signing ceremony for Colorado River Drought Contingency Plans.

The Lower Basin DCP is comprised of proactive water conservation and system efficiency improvement actions to be taken by water users in Arizona, California, and Nevada, and by Reclamation, and additional operational flexibility to promote the creation and long-term storage of conserved water. These actions will result in additional water in Lake Mead and a significant reduction in the risk of reaching critically low elevations. Consistent with the Lower Basin DCP and the Binational Water Scarcity Contingency Plan under Minute 323, Arizona, Nevada, and Mexico were required to make the first-ever water savings contributions of 192,000 acre-feet, 8,000 acre-feet, and 41,000 acre-feet, respectively, in calendar year 2020. In the Upper Basin, development of DCPs was led by the Upper Basin States (Colorado, New Mexico, Utah, and Wyoming) and facilitated by Reclamation. The DCP for the Upper Basin States consists of three elements—Weather Modification (cloud seeding), Drought Response Operations of the Colorado River Storage Project initial units (Flaming Gorge, Aspinall Unit, Navajo, and Glen Canyon/Lake Powell), and Demand Management. Weather modification has been a State-led and funded effort. To date, Reclamation has not been

involved and, in response to new research in the field, is considering support of research-based pilot projects that would advance the science. Drought Response Operations establishes a process for Reclamation, in collaboration with Upper Basin States, to release additional water from upstream Colorado River Storage Project initial unit reservoirs to reduce the risk of Lake Powell reaching critical elevation should it be projected to reach those elevations. Demand Management is a State-based effort to evaluate the feasibility of developing programs in each of the Upper Basin States to support voluntary, compensated, and temporary projects to reduce consumptive use in the Upper Basin and, should those programs be developed, provide storage in the Colorado River Storage Project initial units for conserved water.

Lower Basin Drought Memorandum of Understanding

On December 10, 2014, Reclamation signed a Memorandum of Understanding (MOU) for Lower Basin Pilot Drought Response Actions with Arizona, California, and Nevada, the Southern Nevada Water Authority, the Metropolitan Water District of Southern California, and Central

Arizona Water Conservation District. Under this MOU, the parties agreed to use “best efforts” to implement further voluntary measures designed to add storage to protect levels in Lake Mead from reaching critically low levels, referred to as protection volume. The MOU established goals to create 740,000 acre-feet of protection volume for Lake Mead by the end of 2017, and between 1.5 and 3 million acre-feet in total by the end of 2019. Estimates indicate that approximately 900,000 acre-feet of protection volume was created by the end of 2017, exceeding the goal of 740,000 acre-feet. Additional voluntary contributions totaling approximately 200,000 acre-feet were made in 2018.

System Conservation

In Fiscal Year 2015, Reclamation initiated with Denver Water, Central Arizona Water Conservation District, Metropolitan Water District of Southern California, and Southern Nevada Water Authority the Pilot System Conservation Program, known as the System Conservation Pilot Program in the Upper Basin, for voluntary, compensated, and temporary efforts to conserve water in Lake Powell and Lake Mead for the benefit of all Colorado River System users. Participants in the Pilot System Conservation Program represent all seven Basin States and include agricultural, municipal, and tribal entities.

In the Lower Basin, the Pilot System Conservation Program implemented projects from Fiscal Year 2015 through Fiscal Year 2019 in three phases. In Phases 1 through 3, 16 agricultural, municipal, and tribal projects in Arizona, California, and Nevada were implemented to conserve more than 175,000 acre-feet of Colorado River water in Lake Mead by calendar year 2035, at a cost of \$29.8 million (approximately \$170 per acre-foot). The cost-share between Federal and non-Federal partners is 47 percent Federal funding



Lake Mead, formed by Hoover Dam, between the States of Nevada and Arizona.

and 53 percent non-Federal funding. By the end of calendar year 2019, 94 percent (more than 165,000 acre-feet) of system conservation water conserved through the Pilot System Conservation Program had been stored in Lake Mead.

Upper Basin States, through the Upper Colorado River Commission, administered the System Conservation Pilot Program with Reclamation financial and administrative support and facilitation. The Upper Basin has water users that are more numerous and use smaller quantities of water in general. Subject to local and State administration, 64 projects were implemented over the 4 years of the program resulting in an estimated 47,280 acre-feet of conserved water. Through 2018, when the program ended in the Upper Basin, \$8.5 million (with approximately 24 percent funded by Reclamation and 76 percent funded by non-Federal partners) had been provided for projects. The System Conservation Pilot Program demonstrated that such projects could provide a viable contribution to water savings and the lessons learned are being applied to the States’ consideration of possible future demand management programs.

Binational Cooperation

The United States and Mexico signed Minute 323 to the 1944 Water Treaty in 2017. Minute 323 is effective through 2026 and provides an additional 9 years of operational certainty for water users in the United States and Mexico by extending proactive, cooperative reservoir management strategies agreed to in 2012 through Minute 319. Minute 323 includes the Binational Water Scarcity Contingency Plan whereby additional water savings will be implemented by Mexico when Lake Mead reaches certain low elevation reservoir conditions. This innovative program took effect upon the completion of the Lower Basin Drought Contingency Plan in May 2019.

Environmental Flow Actions

Reclamation participates in partnerships among Federal and non-Federal entities to balance the use of Colorado River water resources with the conservation of native species and their habitats in compliance with records of decisions, and State and Federal laws and regulations.

Glen Canyon Dam Adaptive Management Program

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, primarily in the Grand Canyon. The ongoing 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.

In October 2016, Reclamation and the National Park Service completed a final environmental

impact statement for the *Glen Canyon Dam Long-Term Experimental and Management Plan* (LTEMP) (Reclamation, 2016). The LTEMP establishes a 20-year adaptive management framework for the operation and management of Glen Canyon Dam, consistent with the Grand Canyon Protection Act and other provisions of Federal law. In December 2016, the Department of the Interior finalized a Record of Decision that implements the LTEMP final environmental impact statement preferred alternative and provides focus for the Adaptive Management Program.



The razorback sucker is an endangered native fish found in the Colorado River Basin.

Colorado River Basin Habitat Conservation and Recovery Programs

Other examples of environmental flow activities in the Colorado River Basin include the Upper Colorado River Endangered Fish Recovery Program, San Juan River Basin Recovery Implementation Program, and Lower Colorado River Multi-Species Conservation Program. Due to conservation partnerships among the U.S Fish and Wildlife Service (USFWS), States, Reclamation and other Federal agencies, Tribes, industry, and environmental groups, the razorback sucker (*Xyrauchen texanus*) and humpback chub (*Gila cypha*), both native fish found in the Colorado River Basin, are making a comeback.

In 2020, the USFWS formally proposed downlisting of humpback chub from endangered to threatened based on a species status assessment, 5-year status review, and best available science.

The USFWS concluded the current risk of extinction of humpback chub is low, such that the species is no longer in danger of extinction throughout all of its range. Large populations of adult humpback chub reside in the Colorado and Green Rivers, and the largest population of humpback chub resides in Grand Canyon.

Razorback sucker were recommended for downlisting from endangered to threatened in their 5-year status review, and a proposed rule is expected soon. Abundance of razorback sucker has grown dramatically in the last decade thanks to stocking programs, and large numbers currently reside in the Colorado, Green, and San Juan Rivers. Razorback sucker are also present in Lake Powell, Lake Mead, Lake Mohave, and Lake Havasu.



Delivery of a new wide-head turbine runner for Unit N-5 at Hoover Dam. The turbine arrived on a flatbed truck wrapped in a protective tarp and was flown in using an overhead crane.

Hydropower Improvements

As the elevation of Lake Mead has dropped over the last 20 years, the effectiveness of the existing turbines at producing hydropower at Hoover Dam has been reduced. Reclamation and the Hoover power contractors have made, and will continue to explore, efficiency and reliability improvements for hydropower generation. One of the more significant improvements to date was the 2017 replacement of the 5th of 17 power generating turbines with wide-head turbines, which operate more efficiently at lower lake levels.

New 50-year power contracts (known as Boulder Canyon Project Post-2017 Contracts) for Hoover Dam energy were implemented in 2018 as the prior contracts expired in 2010. Forty-six customers, ranging from electric cooperatives and municipalities to irrigation districts, State agencies, and Tribes, receive power from Hoover Dam. The new contracts gave the existing contractors 95 percent of their existing energy and capacity allocations, while allowing the remaining 5 percent to be marketed to new entities. These contracts provide for continued maintenance and operation of Hoover Dam to generate affordable and reliable hydropower and build on long-standing practices to effectively manage the dam and provide flexibility to address changing conditions in the future.

Partnerships

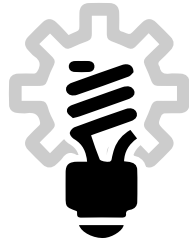
Because of the complexities in the management and operations of the Colorado River System, Reclamation actively and continually partners with a wide variety of entities when engaging in activities and implementing programs to help mitigate the impact of the ongoing drought, and to address future water management challenges. These efforts are designed to reduce future risks and protect one of the most important water resources in the western United States. The partnerships represent tremendous collaboration, coordination, and compromise by all.

Some examples of recent activities where success is measured to a great extent by the support and participation of partners from the Basin States, Tribes, Mexico, non-governmental organizations, academia, and stakeholders include:

- Drought Contingency Plans
- Tribal Water Study
- Minute 323
- The Glen Canyon Dam Adaptive Management Work Group



Minute Oversight Group members' March 2018 site visit to a water conservation project in the Mexicali Valley, Baja California.



SECTION 4

Innovations

Research, Data Development, and Tools

Reclamation's Upper and Lower Colorado Basin Regions launched a multi-faceted research and development program in the Colorado River Basin in 2004. The program was initially focused on research to understand and incorporate hydrologic uncertainty in planning studies, but the scope has evolved over time. The Colorado River Basin Research-to-Operations (CRB R2O) Program currently engages a variety of scientists and government agencies to collaborate on projects that advance Reclamation's use of climate information, hydrology, modeling, and decision science.

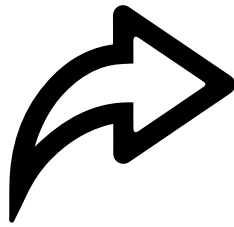
The CRB R2O Program maintains and expands upon a research portfolio that addresses short-, mid-, and long-term planning. Short-term projects are those that are relevant to 24-Month Study modeling activities (0- to 2-year time horizon); mid-term refers to projects that inform Mid-Term Probabilistic Operations Model

activities (2- to 5-year time horizon); and long-term research informs studies performed with the Colorado River Simulation System Model (beyond 5 years). Visit the CRB R2O Program website (<https://www.usbr.gov/lc/region/programs/CRB-R2O-homepage.html>) to view ongoing and completed research.

In fall 2018, Reclamation began coordinating with a diverse group of stakeholder agencies to commission the *Colorado River Basin Climate and Hydrology: State of the Science Report* (Lukas and Payton, 2020). The report synthesizes the large volume of climate and hydrology research and connects the dots among data, methods, models, and projections of future conditions. It will provide an invaluable foundation for future research, planning, and management in the Basin. Visit the Western Water Assessment website (<https://wwa.colorado.edu/publications/reports/CRBreport/>) to access the report and an extensive set of supporting materials including executive summary, individual chapters, webinars, and contact information.



The Grand Canyon, pictured here, was carved by the Colorado River.



Next Steps

There is broad interest from Federal, State, and local governments; Tribes; agricultural users; municipal water suppliers; electrical power users; and conservation and recreation groups in ensuring the sustainability of the Colorado River. The future promises to continue to bring many complex challenges. These include mitigating the impacts of ongoing drought and a changing climate, operating and maintaining aging infrastructure, continuing to improve operational efficiencies, planning and developing new and more reliable water supplies, implementing existing and new water conservation strategies, and ensuring stewardship of environmental and cultural resources.

Strengthening Partnerships

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 entities have implemented programs and initiatives—each with their own set of goals, objectives, approaches, and processes—in various parts of the Basin. Reclamation recognizes that partnering to facilitate cross-program coordination and information exchanges is an important strategy that can allow such programs to work together and focus resources to address Basinwide challenges.

An example of an ongoing, cross-cutting partnership process is the development of new guidelines for the operation of the Colorado River System. On December 13, 2007, the Secretary of the Interior adopted the 2007 Record of Decision (2007 ROD) implementing the *Colorado River Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lake Powell and Lake Mead* (DOI, 2007). The 2007 Interim Guidelines were developed to improve management of Colorado River water supplies; provide water users a greater degree of predictability with respect to the amount of annual water deliveries, particularly under drought and low reservoir conditions; and provide additional mechanisms for the storage and delivery of water supplies in Lake Mead.

The 2007 Interim Guidelines were designed to facilitate a number of non-Federal agreements among the Basin States with the intention that they would remain in effect for a 20-year period through 2026. New operational guidelines will be developed by 2026 to address the long-term sustainable operation of the Colorado River System. To develop a new set of guidelines, Reclamation is relying on strong partnerships with the Basin States, Federal experts across the Department of the Interior, Tribes, non-governmental organizations, academia, and interested stakeholders.

As the first step in the process, in March 2020 Reclamation began a formal review to evaluate the effectiveness of the 2007 Interim Guidelines, a process required by the 2007 ROD. The Review of the Colorado River Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lake Powell and Lake Mead (Review) was a retrospective review of past operations and actions under the 2007 Interim Guidelines and did not consider future activities. Through this Review, Reclamation built a solid technical foundation that informs future consideration of operations and brings partners and the public to a common understanding of past operations and their effectiveness. The Review was completed in December 2020 and the final report is available on Reclamation’s website (<https://www.usbr.gov/ColoradoRiverBasin/#7.D.Review>) (Reclamation, 2020 [Review]).

Future Research

Reclamation will continue to support and facilitate ongoing research critical to furthering the understanding of the Colorado River System. These efforts often include collaborations with the National Center for Atmospheric Research, the Colorado Basin River Forecast Center, and recognized Colorado River experts and researchers. Some of the planned studies focus on the following:

- Upper Basin States maintain diversion records and perform consumptive use modeling at spatial and temporal resolutions that could improve the consumptive use estimates generated by the Colorado Basin River Forecast Center. This project will choose a pilot watershed to demonstrate how such data from the State of Colorado could be incorporated and determine whether the benefits warrant a wider-scale adoption of revised modeling practices by the Colorado Basin River Forecast Center.
- Colorado River Basin temperatures have warmed in recent decades, climate models

agree that the warming trend will continue, and multiple studies have shown that higher temperatures can reduce the amount of streamflow that results from a given amount of precipitation. As such, accounting for this warming trend when generating hydrologic forecasts could produce better streamflow ensembles to support Reclamation’s operations projections. The goal of the resulting ensemble is to capture the warming trend rather than treating observations from the cooler historical years in the early 20th century as equally likely to 21st century conditions.

- A major challenge in framing and conducting long-term planning studies in the Colorado River Basin is the extreme uncertainty in projecting future conditions decades into the future. The field of Decision Making under Deep Uncertainty has arisen to develop methods that can systematically account for this extreme (or “deep”) uncertainty. A new study, estimated to be completed in 2023, will apply innovative approaches and technologies to demonstrate additional steps of Many-Objective Robust Decision Making in the context of Reclamation’s Colorado River Basin planning needs.
- Research of advanced water treatment technologies and applications, such as Direct Potable Reuse and groundwater desalination, continues to be a priority for future water supplies in the Colorado River Basin. Reclamation is focusing on renewable energy based advanced water treatment of brackish groundwater in partnership with the University of Arizona, Northern Arizona University, Colorado School of Mines, the National Renewable Energy Laboratory, and the Navajo Nation. Brackish groundwater, wastewater, impaired, and other non-conventional water supplies are included in the Basin’s future water supply portfolio.



The Laguna Grande restoration site from the air. This site on the Colorado River in Mexico is part of the Minute 319 and Minute 323 restoration program overseen by the International Boundary and Water Commission, United States and Mexico.

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Cover photo: Colorado River at sunset.