BUREAU OF RECLAMATION

Near-term Colorado River Operations

Draft Supplemental Environmental Impact Statement

April 2023

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

Mission Statements

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

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

Photo of Lake Mead with a calcium carbonate ring and Hoover Dam and its intake towers. Photo taken in May 2022 when Lake Mead was in a level 2 shortage condition (1,025' to 1,500' feet above sea level). Photo by Bureau of Reclamation Christopher Clark.

Draft Supplemental Environmental Impact Statement for Near-term Colorado River Operations

Proposed action: Reclamation is proposing to revise the 2007 Interim Guidelines for the operation of Glen Canyon and Hoover Dams beginning in the 2024 operating year to address the potential for continued low-runoff conditions in the Colorado River Basin. The potential impacts of low runoff conditions in the winter of 2022–2023 and the remainder of the interim period (prior to January 1, 2027) pose unacceptable risks to routine operations of Glen Canyon and Hoover Dams; therefore, modified operating guidelines need to be expeditiously developed.

Lead agency: Bureau of Reclamation, Upper Colorado Basin Interior Region 7 and Lower Colorado Basin Interior Region 8

Cooperating agencies:
Bureau of Indian Affairs
National Park Service
Western Area Power Administration
US Fish and Wildlife Service
US Section of the International Boundary and Water Commission

For further information:
Ms. Genevieve Johnson
Bureau of Reclamation, Lower Colorado Basin Region
and
Ms. Marcie Bainson
Bureau of Reclamation, Upper Colorado Basin Region
602-609-6739
CRinterimops@usbr.gov

Compliance with Section 508 of the Rehabilitation Act:

This document is compliant with Section 508 of the Rehabilitation Act. This allows assistive technology to be used to obtain the available information from the document. Due to the nature of graphics, figures, tables, and images occurring in the document, accessibility is limited to a descriptive title for each item.

This page intentionally left blank.

Contents

Tables

Maps

Figures

Appendixes

This page intentionally left blank.

Acronyms and Abbreviations

Acronym/Abbreviation	Full Phrase
1944 Water Treaty	United States-Mexico Treaty on Utilization of Waters of the Colorado and Tijuana Rivers and of the Rio Grande
2006 Flaming Gorge Dam ROD	2006 Record of Decision for the Operation of Flaming Gorge Dam Final Environmental Impact Statement
2007 FEIS	2007 Interim Guidelines Final Environmental Impact Statement
2007 Interim Guidelines	Colorado River Interim Guidelines for Lower Basin Shortages and the Coordinated Operations for Lake Powell and Lake Mead
2007 ROD	2007 Interim Guidelines Record of Decision
2012 Aspinall ROD	2012 Record of Decision for the Aspinall Unit Operations Final Environmental Impact Statement
µg/L	micrograms per liter
af	acre-feet
afy	acre-feet per year
AMSL	(above) mean sea level
AOP	Annual Operating Plan
APE	area of potential effects
Basin	Colorado River Basin
Basin Fund	Upper Colorado River Basin Fund
Basin States	Colorado River Basin States
BCPA	Boulder Canyon Project Act
BIA	Bureau of Indian Affairs
BWSCP	Binational Water Scarcity Contingency Plan
°C	degrees Celsius
CAP	Central Arizona Project
CBRFC	Colorado Basin River Forecast Center
CEQ	Council on Environmental Quality
CFR	Code of Federal Regulations
cfs	cubic feet per second
CLNP	Canyonlands National Park
CO_2e	carbon dioxide equivalent
Compact	Colorado River Compact of 1922
CRIR	Colorado River Indian Reservation
CRMMS	Colorado River Mid-term Modeling System
CRMP	Colorado River Management Plan
CRSP	Colorado River Storage Project
CRSS	Colorado River Simulation System
Dam Fund	Colorado River Dam Fund
DCP	Drought Contingency Plan

DCPA	2019 Colorado River Drought Contingency Plan Authorization Act
Development Fund	Colorado River Basin Development Fund
DO	dissolved oxygen
DOI	United States Department of the Interior
DROA	Drought Response Operations Agreement
EA	Environmental Assessment
EC	Extraordinary Conservation
EIA	United States Energy Information Administration
EIS	Environmental Impact Statement
EOCY	End-of-Calendar-Year
EOWY	End-of-Water-Year
EPA	United States Environmental Protection Agency
ESA	Endangered Species Act
ESP	Ensemble Streamflow Prediction
GCMRC	Grand Canyon Monitoring and Research Center
GCNP	Grand Canyon National Park
GCNRA	Glen Canyon National Recreation Area
GCPA	Grand Canyon Protection Act of 1992
GDP	gross domestic product
GEMSS	Generalized Environmental Modeling System
GHG	greenhouse gas(es)
GIS	geographic information system
GRIC	Gila River Indian Community
GTMax	Generation and Transmission Maximization Model
GWh	giga-watt hours
HCP	Habitat Conservation Plan
HFE	High-Flow Experiment
IBWC	International Boundary and Water Commission
ICS	intentionally created surplus
IID	Imperial Irrigation District
Indian	American Indians
IPAC	Information for Planning and Consultation
ITAs	Indian trust assets
ITCA	Inter-Tribe Council of Arizona
LCR MSCP	Lower Colorado River Multi-Species Conservation Plan
LMNRA	Lake Mead National Recreation Area
Lower Division States	Lower Division States
LTEMP	Long-Term Experimental and Management Plan
m^2	square meter
maf	million acre-feet
M&I	Municipal and Industrial
Mexico	United Mexican States

mg/L	milligrams per liter
MOA	memorandum of agreement
MOU	Memorandum of Understanding
MST	Mountain Standard Time
MT	metric tons
MW	megawatts
MWD	Metropolitan Water District of Southern California
MWh	megawatt hours
NAAQS	National Ambient Air Quality Standards
NDOW	Nevada Department of Wildlife
NEPA	National Environmental Policy Act of 1969
NHPA	National Historic Preservation Act of 1966
NIA	Non-Indian Agriculture
NIB	Northerly International Boundary
NOI	Notice of Intent
NPS	National Park Service
NRHP	National Register of Historic Places
NWR	National Wildlife Refuge
PA	programmatic agreement
PABCO	Pacific Coast Building Products
P-DP	Parker-Davis Project
PM	particulate matter
PO&M	Power Operations and Maintenance
ppb	parts per billion
PPR	present perfected right
PRPA	Paleontological Resource Protection Act
PSD	Prevention of Significant Deterioration
Reclamation	Bureau of Reclamation
RM	river mile
ROD	Record of Decision
Secretary	Secretary of the Interior
SEIS	Supplemental Environment Impact Statement
Service	United States Fish and Wildlife Service
SHPO	State Historic Preservation Office
SIB	Southerly International Boundary
SNWA	Southern Nevada Water Authority
SNWP	Southern Nevada Water Project
SRWYC	Sacramento River Water Year Classification
SUIT	Southern Ute Indian Tribe
TCP	traditional cultural property
TDS	total dissolved solids
THPO	Tribal Historic Preservation Officers

US	United States
USC	United States Code
USGS	United States Geological Survey
USIBWC	United States Section of the International Boundary and Water Commission
WAPA	Western Area Power Administration
WECC	Western Electricity Coordinating Council

Chapter 1. Purpose and Need

1.1 Introduction

The Colorado River Basin (Basin) provides essential water supplies to approximately 40 million people, nearly 5.5 million acres of agricultural lands, hydroelectric renewable power, recreational opportunities, habitat for ecological resources, and other benefits across the southwestern United States and northwestern United Mexican States (Mexico). The Basin occupies an area of approximately 250,000 square miles in the southwestern United States and 3,500 square miles in northwestern Mexico. The Colorado River Compact of 1922 (Compact) divided the Colorado River system into two sub-basins, the Upper Basin and the Lower Basin, and divided the seven states within the Basin into the Upper Division and the Lower Division (**Map 1-1**). Upper Division states include Colorado, New Mexico, Utah, and Wyoming, and the Lower Division includes Arizona, California, and Nevada. Additionally, there are 30 federally recognized Tribes in the Basin (see **Section 4.4** for more information).

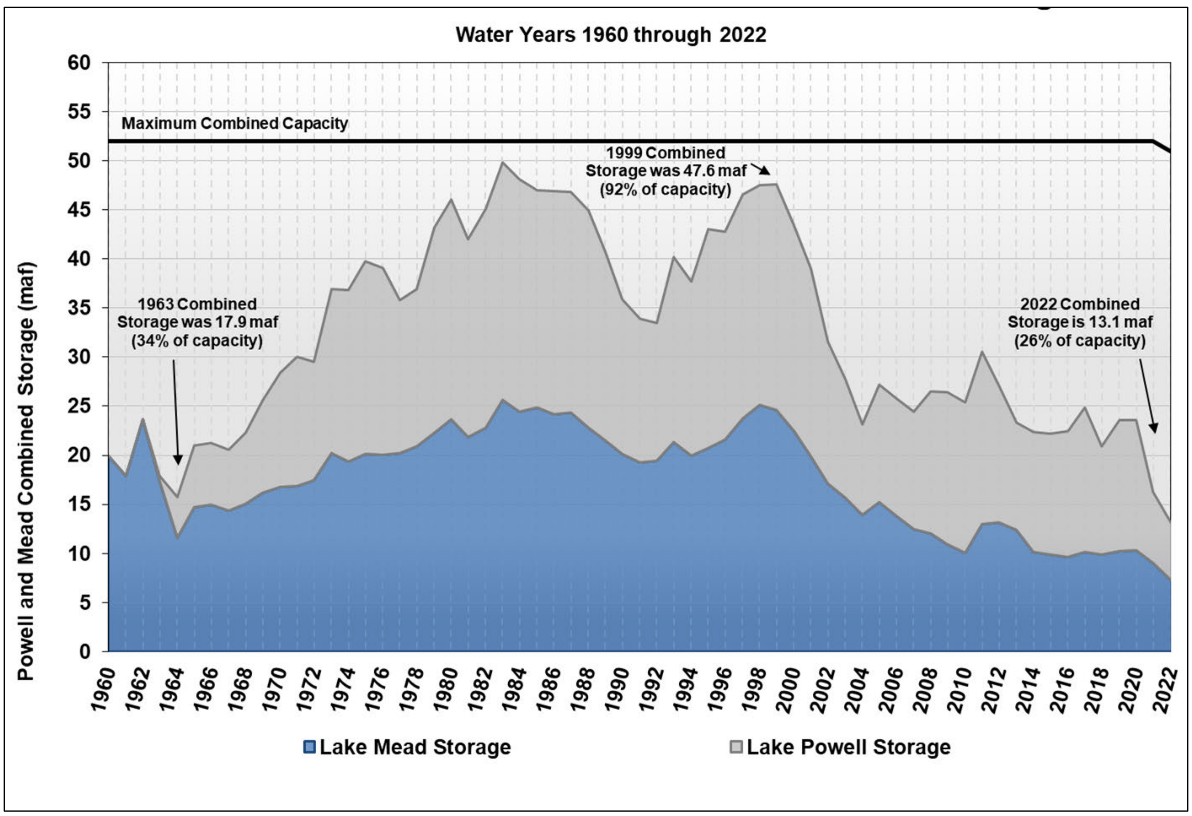
The Secretary of the Interior (Secretary) is vested with the responsibility to manage the mainstream waters of the Colorado River and operate federal facilities pursuant to applicable federal law. This responsibility is carried out consistent with a body of documents that are commonly referred to as the "Law of the River." While there is no single accepted formal definition of this phrase, the Law of the River comprises numerous operating criteria, regulations, administrative decisions, direction included in federal statutes, interstate compacts, court decisions and decrees, an international treaty with Mexico, and contracts.

The Department of the Interior's (Department) Bureau of Reclamation (Reclamation) is tasked with operating the Colorado River system in both the Upper and Lower Basins. Reclamation operates four major dams and various irrigation and diversion structures along the mainstream river, along with five dams on tributaries as part of the Upper Basin Colorado River Storage Project (CRSP). Reclamation operates Hoover Dam and other major facilities in the Lower Basin pursuant to the Boulder Canyon Project Act (BCPA) and other related federal statutes. Operations include managing water supplies and hydrologic power generation. **Appendix A**, Overview of Colorado River Operations, provides additional information about the Law of the River, water apportionment among the Upper and Lower Division States, and river operations.

The Colorado River is approximately 1,450 miles in length, originating along the Continental Divide in Rocky Mountain National Park in Colorado and historically flowing to the Sea of Cortez. Most of the total annual flow in the Basin is runoff from mountain snowmelt. As such, snowpack that accumulates through April provides a reasonable basis for forecasting the majority of the runoff through the remainder of the operating year.[1] Major tributaries to the Colorado River include the Green, San Juan, Yampa, Gunnison, and Gila Rivers.

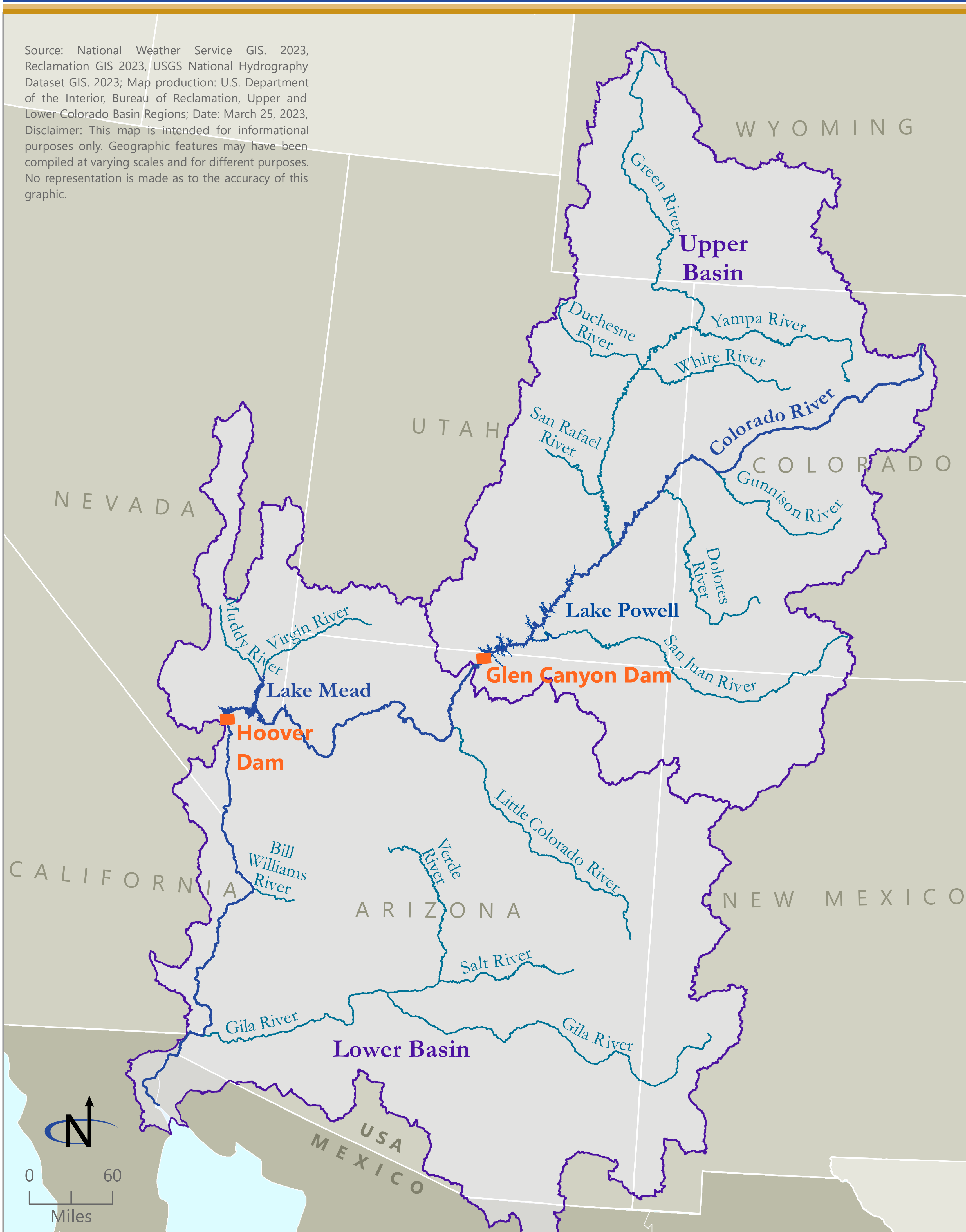
Climate varies significantly throughout the Basin. Most of the Basin is arid or semi-arid, and generally receives less than 10 inches of precipitation per year. In contrast, many of the mountainous areas that rim the northern portion of the Basin receive historical averages exceeding 40 inches of precipitation per year. While the annual flow of the Colorado River and its tributaries varies considerably from year to year, the Basin is currently experiencing a prolonged period of aridification caused by climate change, with extended periods of drought and record low-runoff conditions. The period from 2000 through 2022 is the driest 23-year period in more than a century and one of the driest periods in the last 1,200 years. This has resulted in historically low reservoir levels at Lake Powell and Lake Mead (**Figure 1-1**).

Figure 1-1
Lake Powell and Lake Mead End of Operating Year Storage



[1] The operating year for Glen Canyon Dam runs from October 1 through September 30; the operating year for Hoover Dam runs from January 1 through December 31. Throughout this SEIS, the term "operating year" is used instead of "water year."

— BUREAU OF —
RECLAMATION



Map 1-1
Colorado River Basin and Glen Canyon and Hoover Dams

- Colorado River
- Colorado River tributary
- Dam
- Colorado River Basin, Upper and Lower Basins
- States in the Colorado River Basin (Wyoming, Colorado, Utah, and New Mexico are Upper Division states, and Arizona, California, and Nevada are Lower Division states)

While portions of northwestern Mexico are part of the Basin, these areas are not within the geographic scope of analysis for this SEIS. This is because the SEIS is not considering alternative actions that would change water deliveries to Mexico. The provisions of the 1944 Water Treaty and implementing Minutes are not affected by this SEIS.

This page intentionally left blank.

Reclamation, the Department, Colorado River Basin States (Basin States), Mexico, Tribes, and other Basin water users have undertaken a series of intensive efforts to respond to the extended drought and historically low reservoir levels in the Basin. In December 2007, the Department signed the Record of Decision (ROD) for the Colorado River Interim Guidelines for Lower Basin Shortages and the Coordinated Operations for Lake Powell and Lake Mead (2007 Interim Guidelines; DOI 2007). The 2007 Interim Guidelines, which were anticipated to be in place through 2026, provide operating criteria for Lake Powell and Lake Mead, including provisions designed to provide a greater degree of certainty to water users about timing and volumes of potential water delivery reductions, and additional operating flexibility to conserve and store water in the system. The 2007 Interim Guidelines adopted ranges of releases from Glen Canyon and Hoover Dams that were linked to reservoir elevations in Lake Powell and Lake Mead, respectively. The 2007 Interim Guidelines were adopted for a limited period ("interim") to provide an opportunity for Reclamation and interested entities to gain valuable experience for the management of Lake Powell and Lake Mead under modified operations, with the goal of improving the analytical bases for making future operational decisions, whether during the interim period or after.

Additional key actions that influence operations of the Colorado River include the 2016 Glen Canyon Dam Long-Term Experimental and Management Plan (LTEMP;) and the 2019 Upper Basin and Lower Basin Drought Contingency Plans (DCPs). In 2016, Reclamation and the National Park Service (NPS) developed and implemented the LTEMP to adaptively manage Glen Canyon Dam operations over the next 20 years, consistent with the Grand Canyon Protection Act of 1992 (GCPA) and other provisions of applicable federal law (Reclamation and NPS 2016).[2] In 2019, a number of DCPs were signed, as directed by Congress in the 2019 Colorado River Drought Contingency Plan Authorization Act (DCPA) (Public Law 116-14), outlining strategies to address the ongoing drought and low-runoff conditions in the Upper and Lower Basins.[3] The DCPs addressed operations in both the Upper and Lower Basins.[4] Additional information on the operating criteria, regulations, administrative decisions, and statutes affecting Colorado River operations are included in **Appendix A** of this Supplemental Environmental Impact Statement (SEIS) and in Section 5.1 of the 2007 Interim Guidelines Final Environmental Impact Statement (2007 FEIS; Reclamation 2007).

The Department has taken multiple steps to respond to historic drought and low-runoff conditions in the Basin since 2007, including several unprecedented and emergency actions since 2021:

- **2014 – System Conservation Pilot Program and Memorandum of Understanding (MOU) for Lower Basin Drought Response Actions:** A 2014 agreement among Reclamation and the major municipal water providers (Denver Water, Central Arizona Water Conservation District [CAWCD], Metropolitan Water District of Southern California [MWD], and Southern Nevada Water Authority [SNWA]) in both the Upper and Lower

[2] More information at: https://ltempeis.anl.gov/

[3] More information at: https://www.usbr.gov/dcp/

[4] In particular, given the focus on Glen Canyon Dam operations since 2021, the DCP addressing Upper Basin operations that has been the key operational document is the Drought Response Operations Agreement (DROA). The DROA identifies a process to temporarily move water stored in the CRSP Initial Units above Lake Powell—Blue Mesa (a component of the Aspinall Unit), Flaming Gorge, and Navajo—to Lake Powell when it is projected to approach or decline below elevation 3,525 feet. See more information at: https://www.usbr.gov/dcp/droa.html.

Basin established a pilot program to fund the creation of Colorado River system water through voluntary, measurable reductions in consumptive use for the benefit of all users to help offset declining reservoir elevations.

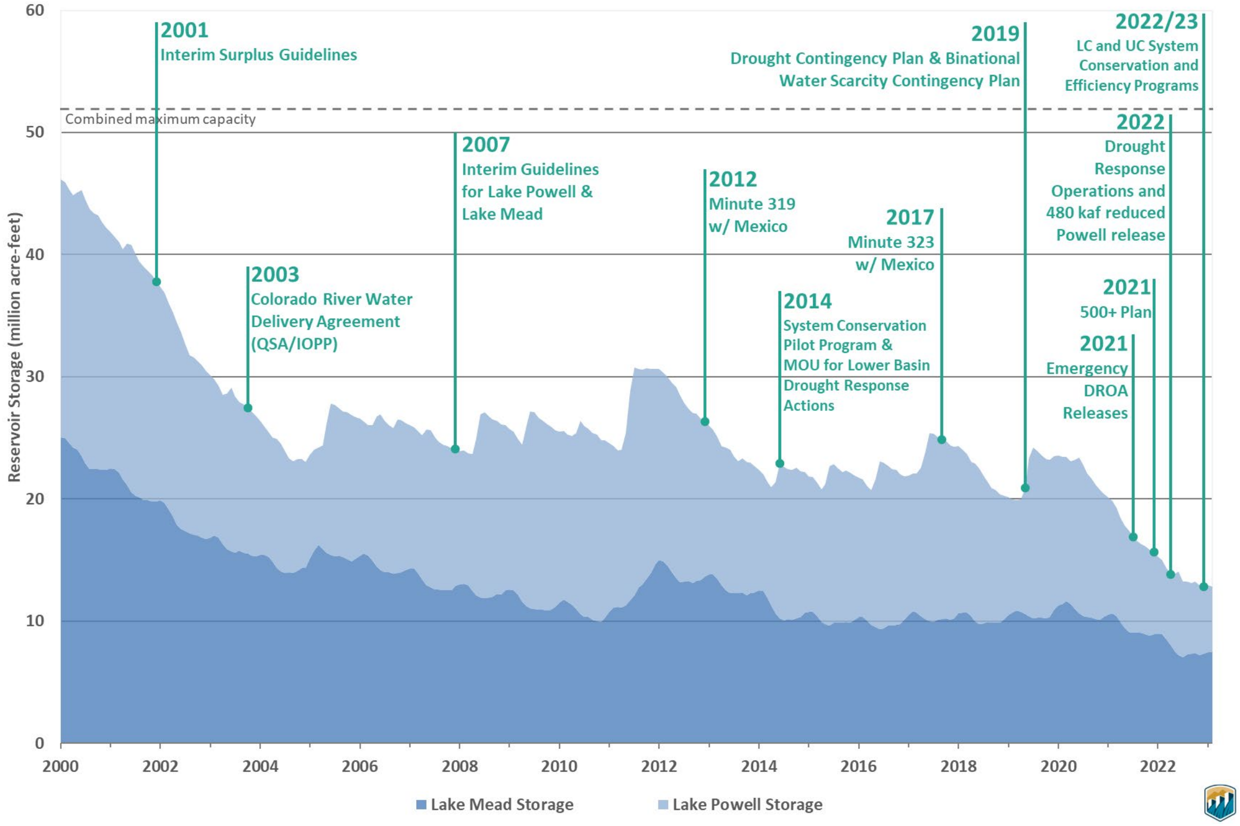
- **2019 – Drought Contingency Plans:** As approved by Congress, the DCPs provide a framework for additional actions to help the Basin adapt to drought. The Upper Basin DCP is designed to reduce the risk of reaching critical elevations at Lake Powell, help assure continued compliance with the Compact, and facilitate and encourage storage of conserved water in the Upper Basin that could help establish the foundation for a demand management program that may be developed in the future. The Lower Basin DCP is designed to require additional contributions of water to Lake Mead storage at predetermined elevations and create new flexibility to incentivize additional voluntary conservation of water to be stored in Lake Mead.
- **2021 – Emergency Drought Response Operations Agreement (DROA) Releases:** Consistent with DROA provisions to protect Lake Powell's target elevation, Reclamation increased releases from the upstream initial units of the CRSP to deliver an additional 181,000 acre-feet (af) of water to Lake Powell by the end of December 2021.
- **2021 – 500 Plus Plan:** Recognizing the history of low-runoff conditions and the variability of flows in the Basin, workgroups concluded an additional 500,000 af or more per year of additional reductions in water use were required. The plan was to conserve additional water above what is required under a Lower Basin shortage condition and contributions under the Lower Basin DCP. The 500 Plus Plan's parties identified and are funding projects in each of the three Lower Division States. The projects include Tribal, agricultural, and municipal water users.
- **2022 – Drought Response Operations and 480,000 acre-feet Reduced Lake Powell Release:** On May 3, 2022, Reclamation announced two separate drought response actions to help increase Lake Powell storage by nearly 1.0 million acre-feet (maf) from May 2022 through April 2023. These actions are approximately 500,000 af of water to be released from Flaming Gorge Reservoir under the DROA and 480,000 af to be held in Lake Powell by reducing Glen Canyon Dam's annual release volume from 7.48 maf to 7.00 maf.[5]
- **2022/2023 – Lower Colorado and Upper Colorado System Conservation and Efficiency Programs:** The programs were created to address the unprecedented drought in the Basin and are part of the commitment made by the Department on August 16, 2022, to address the drought crisis with prompt and responsive actions and investments to create programs and improve water management efforts across the Basin.

Figure 1-2 shows how reservoir elevations have declined despite these efforts.[6]

[5] Letter from Tanya Trujillo, Assistant Secretary for Water and Science, Department, to Thomas Buschatzke, Governor's Representative, State of Arizona, May 3, 2022. https://www.usbr.gov/uc/DocLibrary/Plans/20220503-2022DROA-GlenCanyonDamOperationsDecisionLetter-508-DOI.pdf

[6] This SEIS does not affect the provisions of the 1944 Water Treaty and the implementing minutes; this is because the SEIS is not considering alternative actions that would change water deliveries to Mexico.

Figure 1-2
Actions and Agreements to Protect Lake Powell and Lake Mead Reservoir Elevations (since 2000)



While these actions, especially the DCPs, were intended to preserve Reclamation's ability to undertake post-2026 operational planning with a stable system and avoid crisis planning, Colorado River water supplies continue to decline, resulting in historically low reservoir levels at Lake Powell and Lake Mead. Following adoption of the DCPs in 2019, the Basin experienced three of the lowest consecutive years of inflow on record from 2020 through 2022, with 2021 among one of the lowest inflow years on record. During this time, the combined storage of Lake Powell and Lake Mead declined from about 50 percent to 25 percent of total live capacity. Absent a meaningful and unexpected change in hydrologic conditions and trends, water use patterns, or both, Colorado River reservoirs will continue to decline to critically low elevations, threatening essential water supplies across seven states in the United States and two states in Mexico. It is foreseeable that without appropriate responsive actions and under a continuation of poor hydrologic trends, major Colorado River reservoirs could continue to decline to "dead pool" in the coming years.[7]

Given the declining reservoir elevations, the anticipated continuing trend of low-runoff conditions, and the need to protect infrastructure and Colorado River operations, the Department published a Notice of Intent (NOI) in the *Federal Register* on November 17, 2022. The NOI provided the public

[7] Dead pool refers to elevations at which water cannot be regularly released from a reservoir, which would effectively preclude Colorado River diversions to downstream users.

with the Department's intent to "promptly identify and analyze modified operating guidelines to address current and foreseeable hydrologic conditions" (87 *Federal Register* 69042, 69043 (November 17, 2022)). Under the 2007 Interim Guidelines, 2019 DCPs, and related agreements, Reclamation currently lacks the operational tools necessary to address projected extreme drought conditions and is prioritizing implementation of near-term actions to stabilize the decline in reservoir storage and prevent system collapse. The modification of operating guidelines noted in the *Federal Register* notice is focused on the 2023–2026 period (i.e., the remainder of the interim period). Any actions adopted pursuant to this SEIS process would be separately developed from post-2026 operational planning; however, these tools may inform such later planning.

1.2 Proposed Federal Action

Recognizing the risks facing the Basin, the Department concluded in 2022 that immediate development of additional operational tools for Lake Powell and Lake Mead was necessary to ensure continued operations that are prudent or necessary for safety of dams, public health and safety, and other emergency situations.

Accordingly, Reclamation is proposing revising the 2007 Interim Guidelines for the near-term operation of Glen Canyon and Hoover Dams beginning in the 2024 operating year (beginning October 1, 2023) to address the potential for continued low-runoff conditions in the Basin.[8] Reclamation has concluded that the potential impacts of low-runoff conditions in the winter of 2022–2023 and the remainder of the interim period pose unacceptable risks to routine operations of Glen Canyon and Hoover Dams during the remainder of the interim period (prior to Jan. 1, 2027) and that modified operating guidelines need to be expeditiously developed. Development of modified operating guidelines would also inform potential operations in 2025–2026; however, due to the critically low current reservoir conditions and the potential for worsening drought, the Department recognizes that operational strategies for 2024 may need to be revisited for subsequent operating years to potentially address, for example, 2023 and 2024 hydrology; evaporation, seepage, and system losses; determinations of beneficial use, and additional public health and safety considerations. Given the potential risks to infrastructure[9] and public health and safety, through this SEIS the Department will promptly identify and analyze modified operating guidelines to address current and foreseeable hydrologic conditions. The proposed action would modify the following

[8] The 2024 operating year for Glen Canyon Dam begins Oct. 1, 2023; the 2024 operating year for Hoover Dam begins Jan. 1, 2024.

[9] In recent months, a primary concern for the Department has been to identify and implement actions to ensure that Glen Canyon Dam continues to provide downstream water deliveries as designed and intended (i.e., remains above elevations at/about 3,490 feet above mean sea level). While additional analysis may find that water can be released through the hydropower units when Lake Powell is at slightly lower levels, at this time, 3,490 feet is the cutoff for routine operations. Below this elevation, all water could only be released through Glen Canyon Dam's four river outlet works (reducing operational redundancy and, thus, increasing operational risk for downstream releases). This would create a risk of water supply interruptions to water users that rely on Lake Powell for drinking water supplies; hydropower interruptions to users that rely on Glen Canyon Dam for power supplies; and increased uncertainty regarding downstream releases should Lake Powell continue to decline. As discussed herein, if strategies are adopted to reduce Glen Canyon Dam releases to protect the reliability of routine operations, Lake Mead's water levels will decline at an accelerated rate, increasing risk of Lake Mead declining to critically low levels and threatening water deliveries to those that rely on Lake Mead for water supplies.

sections of the 2007 Interim Guidelines Record of Decision (2007 ROD) published at 73 *Federal Register* 19881 (April 11, 2008): Section 2. Determination of Lake Mead Operation During the Interim Period; Section 6. Coordinated Operation of Lake Powell and Lake Mead During the Interim Period; and Section 7. Implementation of Guidelines. Reclamation has already begun efforts that will lead to preparation of an additional Environmental Impact Statement (EIS) effort for operating guidelines after 2026. See 87 *Federal Register* 37884 (June 24, 2022).

This National Environmental Policy Act of 1969 (NEPA) document analyzes potential modifications to existing reservoir operations. As these analyses are developed, it is important to note that reservoir operation is an inherently ongoing process that must continue while a new operation is being analyzed and determined. As water flows into a reservoir, inflows stored above the dam must be managed in light of the specific physical and operational characteristics of the dam and reservoir. These can include storage capacity, types and elevations of structures to release water, or the need to preserve space for additional inflow as snow melts. As stored water is released from the reservoir, it must be released consistent with the specific physical and operational characteristics of the release structures and the river below, which can include maximum and minimum flow rates; safety restrictions to protect downstream facilities or water uses; considerations to meet ecological conditions, such as the time of year or temperature when water is released; or physical limits where water can no longer be released.

Reservoir operators must routinely—and continuously—adjust releases for these characteristics; there is no option where reservoir operations can simply stop while new rules are developed. Operators must continuously adjust to changing hydrologic conditions—both high-water events, such as being prepared for unexpected snowmelt, and low-water events, such as elevations that approach dead pool—regardless of the timelines or process to determine new reservoir operating rules. These adjustments are further complicated with the coordinated operation of the largest reservoirs in the Basin (Lake Powell and Lake Mead) and the other system reservoirs (both upstream of Lake Powell and downstream of Lake Mead).

In the absence of consensus among all entities affected by changed operations, the Department must consider the overall conditions in the Basin in order to make the most prudent operational decisions. The overall sound and prudent operation of the major reservoirs on the Colorado River system during a period of declining inflows and historically low reservoirs will almost certainly lead to objection by specific entities to the impacts of one or more aspects of water management decisions. The Department will follow applicable federal law and prudent reservoir operations with respect to any modified operating guidelines, recognizing that with current reservoir elevations at historic lows, even one additional low-runoff winter season could have unprecedented adverse consequences across the Basin. In short, every potential option involves difficult water management impacts and unprecedented reductions for entities in the Basin.

1.3 Purpose of and Need for Action

The purpose of the SEIS is to supplement the 2007 Interim Guidelines to modify guidelines for operation of the Glen Canyon and Hoover Dams to address historic drought, historically low reservoirs, and low-runoff conditions in the Basin. The need for the modified operating guidelines is based on the potential that continued low-runoff conditions in the Basin could lead Lake Powell and Lake Mead to decline to critically low elevations, impacting operations through the remainder of the interim period (prior to January 1, 2027).

To ensure Glen Canyon Dam continues to operate under its intended design for purposes of downstream water releases, Reclamation may need to modify current operations and reduce Glen Canyon Dam downstream releases, impacting downstream resources and reservoir elevations at Lake Mead. Consequently, to protect Hoover Dam operations, system integrity, and public health and safety, Reclamation also may need to modify current operations and reduce Hoover Dam downstream releases.

Such modified Hoover Dam operations would, among other issues, address Section 7.B.4 of the 2007 Interim Guidelines as well as the commitments set forth in Section V.B.2 of Exhibit 1 to the 2019 DCPs. Both the 2007 Interim Guidelines and the 2019 DCPs contemplate the need for additional measures to protect Lake Mead elevations, with the DCPs adding the commitment of participating Lower Basin DCP parties to take "individual and collective action in the Lower Basin to avoid and protect against the potential for the elevation of Lake Mead to decline to elevations below 1,020 feet." As noted above, Section 7.D of the 2007 Interim Guidelines contemplates that modified operating provisions may be required if "extraordinary circumstances arise. Such circumstances could include operations that are prudent or necessary for safety of dams, public health and safety, other emergency situations, or other unanticipated or unforeseen activities arising from actual operating experience." The Department finds that such circumstances exist currently.

1.4 Lead and Cooperating Agencies

The Secretary is responsible for the operation of Glen Canyon Dam and Hoover Dam pursuant to applicable federal law. The Secretary is also vested with the responsibility of managing the mainstream waters of the lower Colorado River pursuant to federal law. This responsibility is carried out consistent with the Law of the River. Reclamation, as the agency designated to act on the Secretary's behalf with respect to these matters, is the lead federal agency for the development of this SEIS in accordance with NEPA.

Five federal agencies are cooperating for purposes of assisting with environmental analysis and preparation of this SEIS. These cooperating agencies are the Bureau of Indian Affairs (BIA), the United States Fish and Wildlife Service (Service), the NPS, Western Area Power Administration (WAPA), and the United States Section of the International Boundary and Water Commission (USIBWC).

The BIA has responsibility for the administration and management of lands held in trust by the United States for American Indians (Indian) and Indian Tribes located within the Basin. Developing forestlands, leasing assets on these lands, directing agricultural programs, protecting water and land rights, and developing and maintaining infrastructure and economic development are all part of the BIA's responsibility.

The Service is involved in the conservation, protection, and enhancement of fish, wildlife, and plants and their habitats for the continuing benefit of the American people. The Service manages the resources within four national wildlife refuges along the Colorado River. Among its many other key functions, the Service administers and implements federal wildlife laws, protects endangered species, manages migratory birds, restores nationally significant fisheries, conserves and restores wildlife habitat such as wetlands, and assists foreign governments with international conservation efforts. It also oversees the federal aid program that distributes hundreds of millions of dollars in excise taxes on fishing and hunting equipment to state fish and wildlife agencies.

The NPS administers areas of national significance along the Colorado River, including Glen Canyon National Recreation Area (GCNRA), Grand Canyon National Park (GCNP), and Lake Mead National Recreation Area (LMNRA). The NPS is primarily responsible for conservation of natural and cultural resources and visitor experience (including recreation) in these areas from offices located at Page, Arizona; Grand Canyon, Arizona; and Boulder City, Nevada, respectively. The NPS also grants and administers concessions for the operation of marinas and other recreation facilities at Lake Powell and Lake Mead, as well as concessions' operations along the Colorado River between Glen Canyon Dam and Lake Mead.

WAPA markets and distributes hydroelectric power and related services within a 15-state region of the central and western United States, and it is one of four power marketing administrations within the Department of Energy. Its role is to market and transmit electricity from multi-use water projects. WAPA markets and transmits power generated from the various hydropower plants within the Basin and operated by Reclamation. WAPA customers include municipalities, cooperatives, public utility and irrigation districts, federal and state agencies, investor-owned utilities (only one of which purchases firm power from WAPA), and Indian Tribes throughout the Basin. Wholesale customers, in turn, provide retail electric service to millions of consumers within the seven Basin States.

The International Boundary and Water Commission, United States and Mexico (IBWC) is a binational organization responsible for administration of the provisions of the February 3, 1944, United States-Mexico Treaty on Utilization of Waters of the Colorado and Tijuana Rivers and of the Rio Grande (1944 Water Treaty), which allots Colorado River waters to Mexico. IBWC responsibilities under the 1944 Water Treaty and other international agreements include assuring delivery of Mexico's Colorado River water allotment, protecting lands along the Colorado River from floods by levee and floodway construction projects, addressing border sanitation and other water quality problems, and preserving the Colorado River as the international boundary. The USIBWC and the Mexican Section, which have their headquarters in the adjacent cities of El Paso, Texas, and Ciudad Juarez, Chihuahua, respectively.

1.5 Scope of the SEIS

As a supplement, this SEIS incorporates by reference the original 2007 FEIS. The SEIS focuses on new information, changes in conditions since 2007, and impacts associated with the considered alternatives. The SEIS does not analyze the operations of the entire Colorado River system; rather, it focuses on only addressing the low-runoff and low-level conditions at Glen Canyon and Hoover

Dams. Reclamation does not control the hydrology that affects inflows to Lake Powell. The best available scientific information indicates that low-runoff conditions may persist and worsen with warming conditions in the Basin.

While the potential for the current and persistent low-level conditions was recognized as a low possibility to occur during the interim period as part of the analysis supporting the development of the 2007 FEIS, the 2007 Interim Guidelines, as adopted, did not include provisions that would prevent system collapse under these persistent low-level conditions. Numerous initiatives since 2007 (for example, Minute 323 and the 2019 DCPs) have led to more robust policies; however, notwithstanding these efforts, Reclamation lacks the operating tools to sufficiently protect system operations. Therefore, in this SEIS, Reclamation is proposing operations that are specifically designed to manage the respective reservoirs at lower elevations in order to more reliably maintain congressionally authorized infrastructure, operations, water deliveries, and power generation, and to avoid dead pool conditions as possible.

The hydrologic modeling performed for this SEIS examines scenarios based on flows in the Basin over the past 30 years, which includes 23 consecutive years of drought conditions. To examine even more severe drought conditions, the hydrologic modeling examines Basin flow scenarios with 90 percent and 80 percent of the flows seen over the past 30 years (up to a 20 percent reduction in flows compared with the last 30 years). The SEIS analyzes alternative operational scenarios to react to potential low-level conditions; it does not assess current or future river flow forecasts or attempt to predict actual operations from 2024 to 2026. The SEIS does not include any changes to other operational agreements, such as LTEMP, DCPs, DROA, or Minute 323; operations would implement these agreements per their own terms, unless otherwise stated in this SEIS.

As noted above, on November 17, 2022, Reclamation published a NOI about the preparation of the SEIS (*Federal Register* Vol. 87, No. 221, 69042-69045). It also initiated a public scoping process requesting comments concerning the scope of the analysis, potential alternatives, and identification of relevant information and studies. Reclamation conducted web-based public scoping webinars on November 29 and December 2, 2022, soliciting public comments from interested parties by December 20, 2022. Reclamation also coordinated with representatives from the Basin States, Basin Tribes, and Mexico (through the USIBWC). All public comment letters, along with a scoping summary report (Reclamation 2023), are available on the project website.[10]

Several reservoir and water management decisional documents and agreements that govern the operations of Lake Powell and Lake Mead expire at the end of 2026, including the 2007 Interim Guidelines, the 2019 DCPs, and international agreements between the United States and Mexico pursuant to Minute 323 to the 1944 Water Treaty. Concurrent to this SEIS process, Reclamation is beginning to develop successor domestic agreements for the continued operation of Lake Powell and Lake Mead ("post-2026 operations"). Such post-2026 operations will be analyzed in a separate EIS. See 87 *Federal Register* 37884 (June 24, 2022).

[10] Project website: https://www.usbr.gov/ColoradoRiverBasin/SEIS.html

1.5.1 Affected Region and Interests

The geographic region that would be affected by the proposed alternatives begins with Lake Powell and extends downstream along the Colorado River floodplain to the Southerly International Boundary (SIB) with Mexico. The proposed alternatives would also potentially affect interests of organizations and individuals whose geographic distribution extends beyond the Colorado River floodplain into the service areas of certain water agencies in the Lower Division States.

1.5.2 Relevant Issues

As a result of the scoping process, Reclamation considered issues that may be relevant to the EIS analysis. **Table 1-1** lists the resources and issues potentially significantly affected and addressed in this SEIS. It also lists those that were not considered potentially significant, which are not analyzed in this SEIS. The primary impact drivers are lower flows, changing reservoir levels, and changes in releases and deliveries.

Table 1-1
Resources Considered for Detailed Analysis

Resource	Potentially Significant	Issue Areas
Water Resources		
Hydrologic Resources	Yes	Reservoir elevations, reservoir releases, river flows, groundwater
Water Deliveries	Yes	Apportionments, supply determinations, total water deliveries, shortages, public health and safety
Water Quality	Yes	Salinity, sediment, temperature, dissolved oxygen (DO), metals, nutrients/algae, and perchlorate
Physical Resources		
Air Quality	Yes	Fugitive dust and exposure of reservoir shoreline, greenhouse gas (GHG) emissions from alternative power sources
Visual	Yes	Attraction features, calcium carbonate ring in reservoirs, sediment deltas, Colorado River landscape character between Glen Canyon Dam and Lake Mead, broader landscape character in Lower Division States
Cultural Resources	Yes	Exposure and damage to resources (historical properties) as lake levels recede and river levels drop; disturbance to biological resources, which are contributing elements to Traditional Cultural Properties (TCPs)
Paleontology	Yes	Exposure and damage to resources as lake levels recede
Geology and Soils	No	No potential for effect; sedimentation is addressed in water quality
Minerals	No	No potential for effect
Noise	No	No potential for effect
Biological Resources		
Vegetation	Yes	Riparian and wetland habitat, weeds
Wildlife	Yes	Amphibians, reptiles, raptors, mammals, waterfowl
Special Status Species	Yes	Threatened and endangered species, state and Tribal sensitive species

Resource	Potentially Significant	Issue Areas
Human Environment		
Recreation	Yes	Shoreline public use facilities, reservoir boating, whitewater boating, and fishing
Energy and Hydropower	Yes	Economic analysis and capacity
Economic Impacts	Yes	Regional agricultural economic contributions, economic contributions from recreation activities, economic impacts from municipal and industrial (M&I) water availability
Environmental Justice	Yes	Disproportionate effects on minority and low-income populations
Indian Trust Assets (ITAs)	Yes	Water rights and trust lands
Transportation and Traffic	No	Ferries in Lake Powell are no longer running due to low levels, as analyzed in the 2007 FEIS. Impacts on ferries in Lake Havasu and on the Colorado River below Davis Dam would be the same, as analyzed in the 2007 FEIS.

1.6 Summary of the Contents of this SEIS

This SEIS describes the alternatives considered, the analysis of the potential effects of these alternatives on modified Colorado River operations and associated resources, and environmental commitments associated with the alternatives. The contents of the chapters in this volume are as follows:

- **Chapter 1, Purpose and Need,** includes background information leading to this SEIS, identification of the purpose of and need for the near-term reservoir management strategies of Lake Powell and Lake Mead being considered in the proposed alternatives, and the scope of this SEIS.
- **Chapter 2, Description of Alternatives,** describes the process of formulating alternatives and presents a range of reservoir operation strategies and guidelines considered under each alternative, as well as alternatives considered but eliminated from detailed analysis.
- **Chapter 3, Affected Environment and Environmental Consequences,** describes the affected environment for the proposed alternatives and presents evaluations of potential impacts that could result from implementation of the alternatives under consideration. The discussion also addresses environmental consequences (i.e., potential effects of the action alternatives that could occur compared with the No Action Alternative). A methodology, summary, and discussion of cumulative impacts is also included under each resource topic.
- **Chapter 4, Consultation and Coordination,** describes the public involvement process, including public notices, scoping meetings, and hearings. This chapter also describes the coordination with federal and state agencies, Indian Tribes, and Mexico (through the USIBWC) during the preparation of this document and any permitting or approvals that may be necessary for implementation of the proposed alternatives.

In addition to the above, this document includes a list of acronyms used throughout this SEIS; a glossary of commonly used terms; a list of references cited in the SEIS; a list of persons contributing to the preparation of the SEIS; and an index. This document also contains appendixes that consist of documents and other supporting material that provide detailed historical background and technical information concerning the proposed alternatives.

This page intentionally left blank.

Chapter 2. Description of the Alternatives

2.1 Development of the Alternatives

This chapter discusses the process used to define, develop, and analyze the No Action Alternative, as well as a range of reasonable action alternatives, for implementing the proposed federal action. As discussed in **Chapter 1**, Purpose and Need, and in the NOI to prepare this SEIS (87 *Federal Register* 69042, November 17, 2022), Reclamation is proposing modifications to the following sections of the 2007 2007 ROD published at 73 *Federal Register* 19881 (April 11, 2008), which were analyzed in the 2007 FEIS:

- **Section 2. Determination of Lake Mead Operation During the Interim Period.** Reclamation is analyzing a revision of Section 2.D, Shortage Conditions, to decrease the quantity of water that would be apportioned for consumptive use in the Lower Division States in years of low flow and low reservoir elevations.
- **Section 6. Coordinated Operation of Lake Powell and Lake Mead During the Interim Period.** Reclamation is analyzing a revision of Sections 6.C, Mid-Elevation Release Tier, and 6.D, Lower Elevation Balancing Tier, to reduce the quantity of water released from Glen Canyon Dam in years of low flow and low reservoir elevations.
- **Section 7. Implementation of Guidelines.** Reclamation is analyzing a revision of Section 7.C, Mid-Year Review, to allow for potential determinations in a mid-year review that would allow for reduced deliveries from Lake Mead, pursuant to Section 2 of the 2007 Interim Guidelines.

The descriptions of the No Action Alternative, Action Alternative 1, and Action Alternative 2, below, discuss how each alternative would modify these sections. The action alternatives provide operations that are specifically designed to manage the respective reservoirs at lower elevations in order to more reliably maintain congressionally authorized infrastructure, operations, water deliveries, and power generation, and to avoid dead pool conditions as possible.

Reclamation developed two action alternatives for analysis in this SEIS. As noted in the November 17, 2022, NOI, the Final SEIS is anticipated to be available with a ROD, as appropriate, in late summer 2023. The NOI (87 *Federal Register* 69045) further provided that:

> In addressing operations for 2023–24, Reclamation is committed to using the best available information to develop near-term operating guidelines while longer-term approaches are developed. Reclamation anticipates using the work and analysis from this SEIS process to also inform operating guidelines for the 2025–2026 period, which will undergo any additional NEPA analysis as required.

Accordingly, the alternatives developed in this SEIS are focused, as an initial matter, on the 2024 operating year, and recognize that further refinements to operating guidelines for the 2025–2026 period may be required.

These action alternatives reflect input from Reclamation, the cooperating agencies, stakeholders, and other interested parties, including comments submitted during the SEIS public scoping period. To date, no submission has garnered complete consensus across the Basin. However, among the input received, Reclamation received written proposals for alternatives, or components thereof, that met the proposed federal action's purpose and need. Specifically, Reclamation received a proposal from six Basin States (Arizona, Colorado, Nevada, New Mexico, Utah, and Wyoming) and a proposal from California. Reclamation carefully reviewed these proposals, along with others received.

While no external proposals have been carried forward as full alternatives in this SEIS, several of these proposals have been analyzed in **Appendix B**, Hydrologic Modeling of External Proposals, in terms of their hydrologic performance over the remainder of the interim period. As noted in more detail in **Appendix B**, the action alternatives identified in this SEIS more closely mimic the full range of the states' submissions for the 2025–2026 period, given the larger Lower Basin reductions discussed below in each action alternative.

A description of each alternative, including elements common to all alternatives, follows.

2.2 Preferred Alternative

Reclamation has not identified a preferred alternative at this time. The preferred alternative will be identified in the Final SEIS, as required by Council on Environmental Quality (CEQ) NEPA regulations (43 Code of Federal Regulations [CFR] 1502.14(e)).

2.3 Environmentally Preferable Alternative

In accordance with CEQ NEPA regulations (43 CFR 1502.2(b)), Reclamation will identify the environmentally preferable alternative in the ROD for this SEIS.

2.4 Implementation

The Department anticipates adopting modified guidelines prior to determining operations for the 2024 operating year. For Glen Canyon Dam and the other Upper Basin reservoirs, operations for the 2024 operating year begin October 1, 2023; for Hoover Dam, they begin January 1, 2024. Consistent with the 2007 Interim Guidelines, the DCPs, and Minute 323, these operating determinations will be based on projected January 1, 2024, reservoir conditions at Lake Powell and Lake Mead based on the August 2023 24-Month Study. The Department may select different parts of any of the alternatives to best meet the purpose and need. The action alternatives provide operational tools for continued low-flow conditions in light of the fact that current operating guidelines provide insufficient protection against reservoirs declining to critically low elevations.

The analysis in the SEIS has a primary, but not exclusive, focus on implementation of each alternative for the 2024 operating year. The focus on this 2024 operating year time frame is based on the need to promptly develop additional operational tools in light of historically low reservoir elevations. The alternatives also describe operations for 2025–2026. The SEIS analyzes the alternatives for the 2025–2026 time frame across affected resource areas to the extent that information is available. There is more uncertainty in the 2025–2026 analysis (both from a hydrologic and resource impact standpoint); accordingly, the Department may select an alternative to apply in the 2024 operating year, with future analysis, as needed, to be performed before potentially revising the selected alternative for 2025–2026 operations.

2.5 Common to All Alternatives

Under all alternatives, operations would continue pursuant to the continued implementation of existing agreements that control operations of Glen Canyon and Hoover Dams. Regarding coordinated reservoir operations, the Equalization and Upper Elevation Balancing Tiers for determining the annual Lake Powell release, based on the volume of water in storage or the corresponding elevation of Lake Powell and Lake Mead, would be the same as described in the 2007 Interim Guidelines for all alternatives.

For all alternatives, Section III.B. of Exhibit 1 (Lower Basin Drought Contingency Operations) to the Lower Basin Drought Contingency Plan Agreement, as executed pursuant to Public Law 116-14 (2019), provides that DCP contributions are made based on the projected elevation of Lake Mead on January 1, using Reclamation's August 24-Month Study. DCP contributions will continue to be determined based on the elevation of Lake Mead as projected in the 24-Month Study and are in addition to the shortage volumes described in Section 2.D of the 2007 Interim Guidelines.

As noted in **Chapter 1**, there has been extensive focus on the goal of operating Glen Canyon Dam as intended for long-term operations (that is, to keep Lake Powell at or above an elevation of 3,490 feet). However, it is reasonably foreseeable that Lake Powell may decline below this critical elevation during the 2024–2026 period. In such an event, at any given time, Glen Canyon Dam would be operated with all available river outlet works. For the purpose of analyzing impacts in this SEIS, Reclamation anticipates having three of the four river outlet works available, due to the need for routine maintenance.

Reclamation notes that intensive efforts are underway to facilitate water conservation actions in the Basin under a number of programs, including the recent congressional prioritization of funding through 2026 of $4 billion for drought mitigation in western states, with priority given to the Basin and other basins experiencing comparable levels of long-term drought (Public Law 117-169 at Section 50233; August 16, 2022). The ongoing implementation and effectiveness of these essential efforts will help determine the degree to which revised operations will be implemented.

The Secretary intends to use this SEIS NEPA process to facilitate implementation of Section 7.B.2 of the 2007 Interim Guidelines with respect to the potential implementation of the alternatives, beginning in the 2024 operating year.

Allocation of Colorado River water to Mexico is governed by the 1944 Water Treaty. To assess the potential effects of the alternatives in this SEIS, certain modeling assumptions (discussed in **Chapter 3**) are used that display projected water deliveries to Mexico. These assumptions include continued implementation of Minute 323 to the 1944 Water Treaty.

2.6 No Action Alternative

The No Action Alternative describes the continued implementation of existing agreements that control operations of Glen Canyon and Hoover Dams. These include the 2007 Interim Guidelines for the remainder of the interim period (through the 2026 operating year) and agreements adopted pursuant to the DCPA (Public Law 116-14).

2.6.1 Shortage Guidelines

Table 2-1, below, shows the Lower Basin shortages under the 2007 Interim Guidelines and contributions under the 2019 DCPs modeled under the No Action Alternative in calendar year 2024. The applicable operating condition would continue to be based on the August 24-Month Study projections of the January 1 system storage and reservoir water surface elevations for the following calendar year.[1]

Table 2-1
Lower Division States' Shortages and DCP Contributions, No Action Alternative*

Lake Mead Elevation (feet)	No Action Alternative		
	2007 ROD** Shortage (1,000 af)	2019 DCP Contributions (1,000 af)	Total Shortage + Contributions (1,000 af)
1,090 – >1,075	0	200	200
1,075 – 1,050	333	200	533
<1,050 – >1,045	417	200	617
1,045 – >1,040	417	450	867
1,040 – >1,035	417	500	917
1,035 – >1,030	417	550	967
1,030 – 1,025	417	600	1,017
<1,025 – 1,000	500	600	1,100
<1,000 – 975	500	600	1,100
<975 – 950	500	600	1,100
<950	500	600	1,100

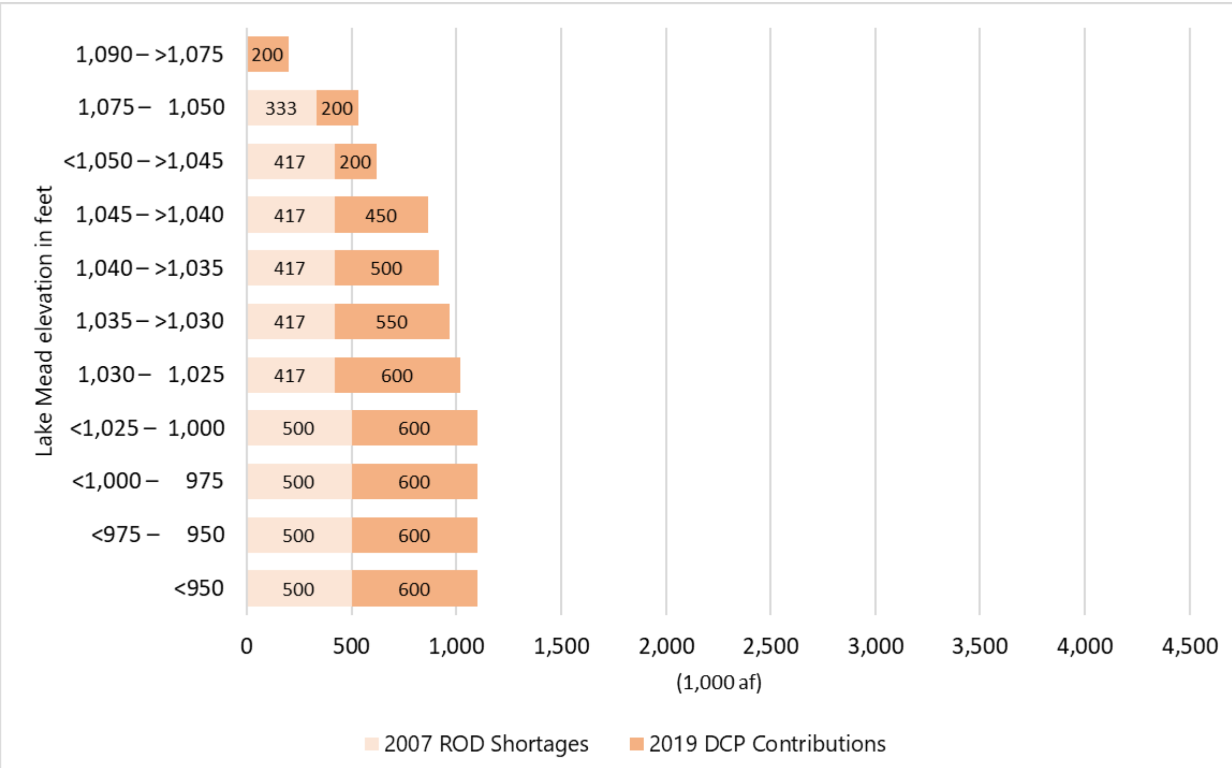
* This table only shows combined Lower Division State shortage volumes and DCP contributions. In addition to the volumes shown in this table, the analysis for each alternative includes water delivery reductions to Mexico under low-elevation reservoir conditions and Mexico's savings that contribute to the Binational Water Scarcity Contingency Plan (BWSCP), in accordance with Minute 323 to the 1944 Water Treaty.
** Shortages listed in the 2007 ROD

[1] "24-Month Study" refers to the operational study that reflects the current Annual Operating Plan (AOP) that is updated each month by Reclamation to project future reservoir contents and releases. The projections are updated each month using the previous month's reservoir contents and the latest inflow and water use forecasts.

Figure 2-1 shows a graphical view of Lower Basin shortages and contributions from the 2007 Interim Guidelines and 2019 DCPs modeled under the No Action Alternative.

These same assumptions for Lower Basin shortages, DCP contributions, and deliveries to Mexico under the 1944 Water Treaty and Minute 323 were modeled in calendar years 2025 and 2026.

Figure 2-1
Modeled Lower Basin Shortages and DCP Contributions, No Action Alternative



2.6.2 Coordinated Reservoir Operations

Under the No Action Alternative, the annual Lake Powell release is based on the volume of water in storage or the corresponding elevation of Lake Powell and Lake Mead, as described in the operational tiers below (see **Table 2-2**). The applicable operational tier would continue to be based on the August 24-Month Study projections of the January 1 system storage and reservoir water surface elevations for the following operating year.

Mid-Elevation Release Tier

When Lake Powell's elevation is projected to be below 3,575 feet and at or above 3,525 feet on January 1, a release in the amount of 7.48 maf would be made if the projected January 1 elevation of Lake Mead is at or above 1,025 feet. If the projected January 1 Lake Mead elevation is below 1,025 feet, a release of 8.23 maf from Lake Powell would be made.

Table 2-2
Lake Powell Operational Tiers, No Action Alternative

Lake Powell Operational Tiers (subject to April adjustments or mid-year review modifications)		
Lake Powell Elevation (feet)	**Lake Powell Operational Tier**	**Lake Powell Active Storage** (maf)*
3,700	**Equalization Tier** Equalize, avoid spills, or release 8.23 maf	**23.31**
3,636–3,666 (see Table 2.3-1 in the 2007 FEIS)	**Upper Elevation Balancing Tier** Release 8.23 maf; if Lake Mead <1,075 feet, balance contents with a minimum/maximum release of 7.0/9.0 maf	**14.65–18.36** (2008–2026)
3,575	**Mid-Elevation Release Tier** Release 7.48 maf; if Lake Mead <1,025 feet, release 8.23 maf	**8.90**
3,525	**Lower Elevation Balancing Tier** Balance contents with a minimum/maximum release of 7.0/9.5 maf	**5.55**
3,370		**0**

*Active storage values have been updated from 2007 based on the 2018 bathymetry.

Lower Elevation Balancing Tier

When the projected January 1 Lake Powell elevation is below 3,525 feet, the contents of Lake Mead and Lake Powell would be balanced, if possible, within the constraint that the release from Lake Powell would be no more than 9.5 maf and no less than 7.0 maf.

2.6.3 Implementation of Guidelines

To allow for better overall water management during the interim period, a mid-year review may be undertaken to consider revisions to the AOP based on the April 1 final forecast of the April through July runoff, currently provided by the National Weather Service's Colorado Basin River Forecast Center, and other relevant factors, such as actual runoff conditions, actual water use, and water use projections. In the mid-year review, the AOP may be modified to make a determination that a different operational tier will apply for the remainder of the year or operating year, as appropriate, or that an amount of water other than that specified in the applicable operational tier will be released for the remainder of the year or operating year, as appropriate. Revisions to shortages—compared with the AOP—associated with Lake Mead's elevation determinations in the mid-year review can be revised only to allow for additional deliveries from Lake Mead; they cannot be revised for reduced deliveries.

2.6.4 Drought Contingency Plan

Pursuant to the DCPA (Public Law 116-14), Congress directed the Secretary to carry out a number of drought-related agreements, including mandatory implementation of specific provisions for operation of Colorado River system reservoirs in the Upper and Lower Basins. The agreements include the Upper Basin DCP, which affects operations above Lee Ferry, and the Lower Basin DCP, which affects operations below Lee Ferry (primarily regarding Hoover Dam operations). Both the Upper Basin DCP and the Lower Basin DCP are supplemental to and in furtherance of the goals and operations contained in the 2007 Interim Guidelines.

Continuing current operations of Lake Powell and Lake Mead in extreme low-runoff scenarios would create the potential for water levels in one or both reservoirs to decline to dead pool, thereby preventing operation of Glen Canyon Dam or Hoover Dam, or both, to provide water supplies in the Basin. In such reasonably foreseeable circumstances, the No Action Alternative would not meet the purpose of and need for the federal action because it would not "ensure that Glen Canyon Dam continues to operate under its intended design" and would not "protect Hoover Dam operations, system integrity, and public health and safety " (see **Section 1.3**, Purpose of and Need for Action).

2.7 Action Alternative 1

This alternative describes a set of actions adopted pursuant to Secretarial authority under applicable federal law. Unlike current operations that were developed, and are being implemented, pursuant to basin-wide consensus (for example, the 2007 Interim Guidelines and the 2019 DCPs), Action Alternative 1 models changes to operations for both Glen Canyon Dam and Hoover Dam as developed by Reclamation. Action Alternative 1 includes assumptions for reduced releases from Glen Canyon Dam and additional Lower Basin shortages based on the concept of priority.[2] Action Alternative 1 models releases between 6.0 maf and 8.23 maf from Lake Powell when it is below 3,575 feet, with potentially lower releases to preserve the elevation of 3,500 feet.[3]

Action Alternative 1 models progressively larger additional shortages as Lake Mead's elevation declines. It also models larger additional shortages in 2025–2026 as compared with 2024. The total shortages and DCP contributions in 2024, as modeled, are limited to 2.083 maf. This is because this is the maximum volume analyzed in the 2007 FEIS, and to analyze shortages greater than 2.083 maf would require additional detailed analysis and stakeholder coordination. Working within this range of previously analyzed impacts will facilitate completing this SEIS process in the time available in advance of the 2024 operating year. Delaying operational decisions to perform additional analyses would not meet the express purpose of and need for this action.

For all operations, including, but not limited to when Lake Powell is approaching 3,500 feet or when Lake Mead is approaching 950 feet, the Secretary reserves the right to operate Reclamation facilities to address extraordinary circumstances, as described in Section 7(D) of the 2007 Interim Guidelines, including "operations that are prudent or necessary for safety of dams, public health and safety,

---

[2] Priority refers the distribution of Colorado River water in the Lower Division States of Arizona, California, and Nevada as subject to laws, judicial rulings and decrees, contracts, interstate compacts, and operating criteria, known as the "Law of the River," which apportion available water between the states and establish certain priorities in use.
[3] The action alternatives would protect an elevation of 3,500 feet in Lake Powell to provide a buffer above minimum power pool, which is at 3,490 feet.

other emergency situations, or other unanticipated or unforeseen activities arising from actual operating experience."

2.7.1 Shortage Guidelines

Table 2-3 shows the Lower Basin shortages under the 2007 Interim Guidelines, contributions under the 2019 DCPs, and additional shortages modeled under Action Alternative 1 in calendar year 2024. Assumptions regarding the breakdown of shortages and contributions by state, according to priority, are shown in **Table 2-4**. Reclamation may consider additional shortages in Shortage Condition Year 2025 and 2026 (see **Table 2-5**). This consideration would occur as part of the future analysis referenced in **Section 1.2** before the 2025 operating year operating condition determination.

Figure 2-2 shows a graphical view of Lower Basin shortages and contributions from the 2007 Interim Guidelines and the 2019 DCPs plus additional shortages modeled under Action Alternative 1.

Whenever Lake Mead's content is projected to be below an elevation of 1,000 feet, based on the January 1 projection or a mid-year review, additional reductions may be needed to protect the minimum power pool (elevation 950 feet) and to reduce the risk of declining to dead pool (elevation 895 feet).

Table 2-3
Lower Division States' Shortages and DCP Contributions, Action Alternatives 1 and 2 (2024)*

Lake Mead Elevation (feet)	No Action Alternative			Additional Shortages under Action Alternatives 1 and 2 (2024)	
	2007 ROD Shortages (1,000 af)	2019 DCP Contributions (1,000 af)	No Action Total (1,000 af)	2024 Additional Shortages (1,000 af)	2024 Total Shortages + Contributions (1,000 af)
1,090 – >1,075	0	200	200	200	**400**
1,075 – 1,050	333	200	533	533	**1,066**
<1,050 – >1,045	417	200	617	617	**1,234**
1,045 – >1,040	417	450	867	867	**1,734**
1,040 – >1,035	417	500	917	1,166	**2,083**
1,035 – >1,030	417	550	967	1,116	**2,083**
1,030 – 1,025	417	600	1,017	1,066	**2,083**
<1,025 – 1,000	500	600	1,100	983	**2,083**
<1,000 – 975	500	600	1,100	983	**2,083**
<975 – 950	500	600	1,100	983	**2,083**
<950	500	600	1,100	983	**2,083**

* This table only shows combined Lower Division State shortage volumes and DCP contributions. In addition to the volumes shown in this table, the analysis for each alternative includes water delivery reductions to Mexico under low-elevation reservoir conditions and Mexico's savings that contribute to the Binational Water Scarcity Contingency Plan, in accordance with Minute 323 to the 1944 Water Treaty.

Table 2-4
Lower Division States' Shortages and DCP Contributions by State, Action Alternative 1 (2024)

Lake Mead Elevation (feet)	2007 ROD Shortage + 2019 DCP Contributions (1,000 af)				2024 Action Alternative 1 Additional Shortage* (1,000 af)				2024 Total Shortages + Contributions (1,000 af)			
	AZ	NV	CA	Total	AZ	NV	CA	Total	AZ	NV	CA	Total
1,090 – >1,075	192	8	0	200	192	8	0	200	384	16	0	400
1,075 – 1,050	512	21	0	533	511	22	0	533	1,023	43	0	1,066
<1,050 – >1,045	592	25	0	617	593	24	0	617	1,185	49	0	1,234
1,045 – >1,040	640	27	200	867	1,025	42	0**	1,067	1,665	69	200	1,734***
1,040 – >1,035	640	27	250	917	1,098	56	12	1,166	1,738	83	262	2,083
1,035 – >1,030	640	27	300	967	1,098	56	0**	1,154	1,738	83	300	2,083***
1,030 – 1,025	640	27	350	1,017	1,098	56	0**	1,154	1,738	83	350	2,083***
<1,025 – 1,000	720	30	350	1,100	1,018	53	0**	1,071	1,738	83	350	2,083***
<1,000 – 975	720	30	350	1,100	1,018	53	0**	1,071	1,738	83	350	2,083***
<975 – 950	720	30	350	1,100	1,018	53	0**	1,071	1,738	83	350	2,083***
<950	720	30	350	1,100	1,018	53	0**	1,071	1,738	83	350	2,083***

*The additional shortage volumes decrease at elevation 1,025 feet because the shortages under the 2007 Interim Guidelines increase by the same amount. Therefore, the additional shortage amounts necessary to get to the 2.083 maf total are lower.

**In this elevation tier, the 2019 DCP contributions for California exceed what would be required under Action Alternative 1. As a result, no additional shortage is required in this elevation tier for California.

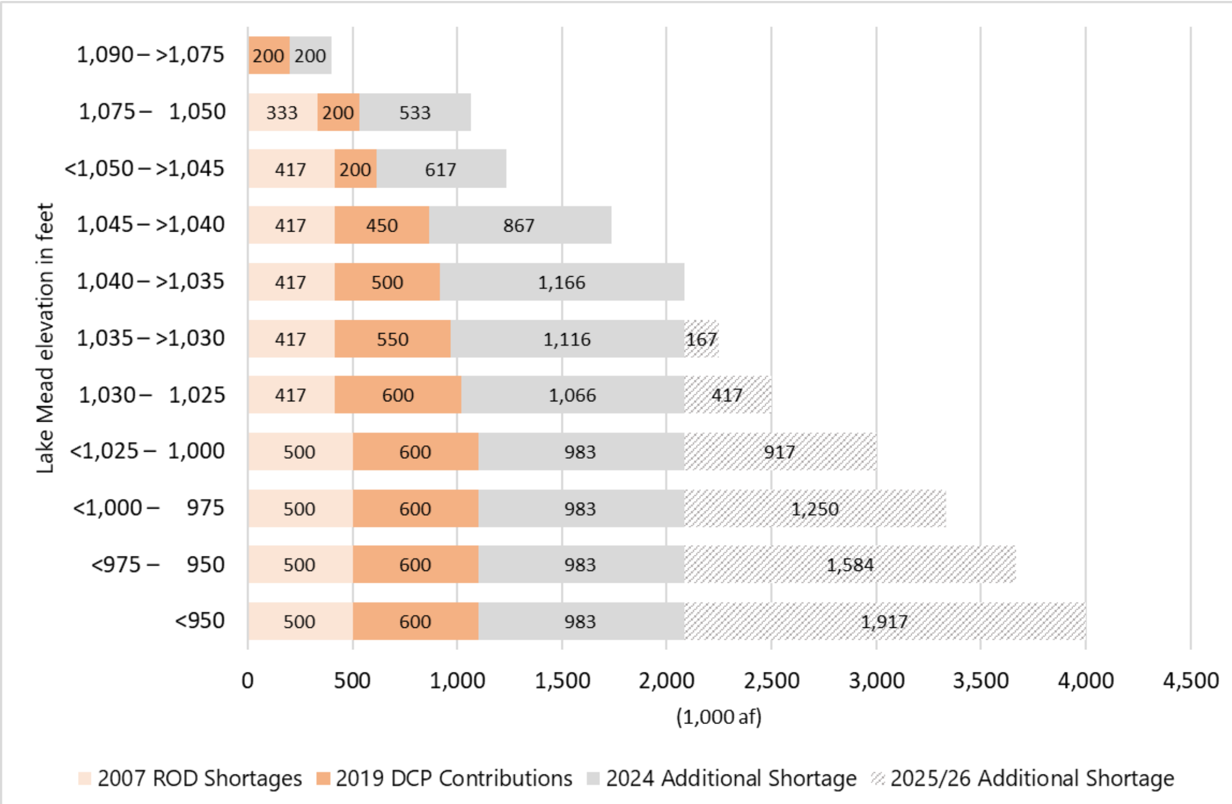
***Because the 2019 DCP contributions for California exceed the 2024 total shortage and contribution volume as modeled by the Shortage Allocation Model, the sum of the three state totals exceeds the total shortage and contribution volume. While the total amount of the three states' total shortage and contribution volume exceeds 2.083 maf in the elevation tiers below elevation 1,035 feet, the ROD would not exceed a total shortage and contribution volume of 2.083 maf in calendar year 2024.

Table 2-5
Lower Division States' Shortages and DCP Contributions, Action Alternatives 1 and 2 (2025–2026)*

Lake Mead Elevation (feet)	No Action Alternative			Additional Shortages under Action Alternatives 1 and 2 (2025–2026)	
	2007 ROD Shortage (1,000 af)	2019 DCP Contributions (1,000 af)	No Action Total (1,000 af)	2025–2026 Additional Shortage** (1,000 af)	2025–2026 Total Shortages + Contributions (1,000 af)
1,090 – >1,075	0	200	200	200	**400**
1,075 – 1,050	333	200	533	533	**1,066**
<1,050 – >1,045	417	200	617	617	**1,234**
1,045 – >1,040	417	450	867	867	**1,734**
1,040 – >1,035	417	500	917	1,166	**2,083**
1,035 – >1,030	417	550	967	1,283	**2,250**
1,030 – 1,025	417	600	1,017	1,483	**2,500**
<1,025 – 1,000	500	600	1,100	1,900	**3,000**
<1,000 – 975	500	600	1,100	2,233	**3,333**
<975 – 950	500	600	1,100	2,567	**3,667**
<950	500	600	1,100	2,900	**4,000**

* This table only shows combined Lower Division State shortage volumes and DCP contributions. In addition to the volumes shown in this table, the analysis for each alternative includes water delivery reductions to Mexico under low-elevation reservoir conditions and Mexico's savings that contribute to the Binational Water Scarcity Contingency Plan, in accordance with Minute 323 to the 1944 Water Treaty.
The scope of this NEPA analysis, including potential actions in 2025–2026, is discussed further in **Sections 1.2 and **1.5**.

Figure 2-2
Modeled Lower Basin Shortages and DCP Contributions, Action Alternatives 1 and 2



2.7.2 Coordinated Reservoir Operations

Under Action Alternative 1, the annual Lake Powell release is based on the volume of water in storage or the corresponding elevation of Lake Powell and Lake Mead, as described in the operational tiers below (see **Table 2-6**). The Equalization and Upper Elevation Balancing Tiers are the same as under the No Action Alternative. The Mid-Elevation Release Tier and Lower Elevation Balancing Tier are combined into a single Lower Elevation Release Tier, and a Protection Level is also included. The applicable operational tier is based on the August 24-Month Study projections of the January 1 system storage and reservoir water surface elevations for the following operating year.

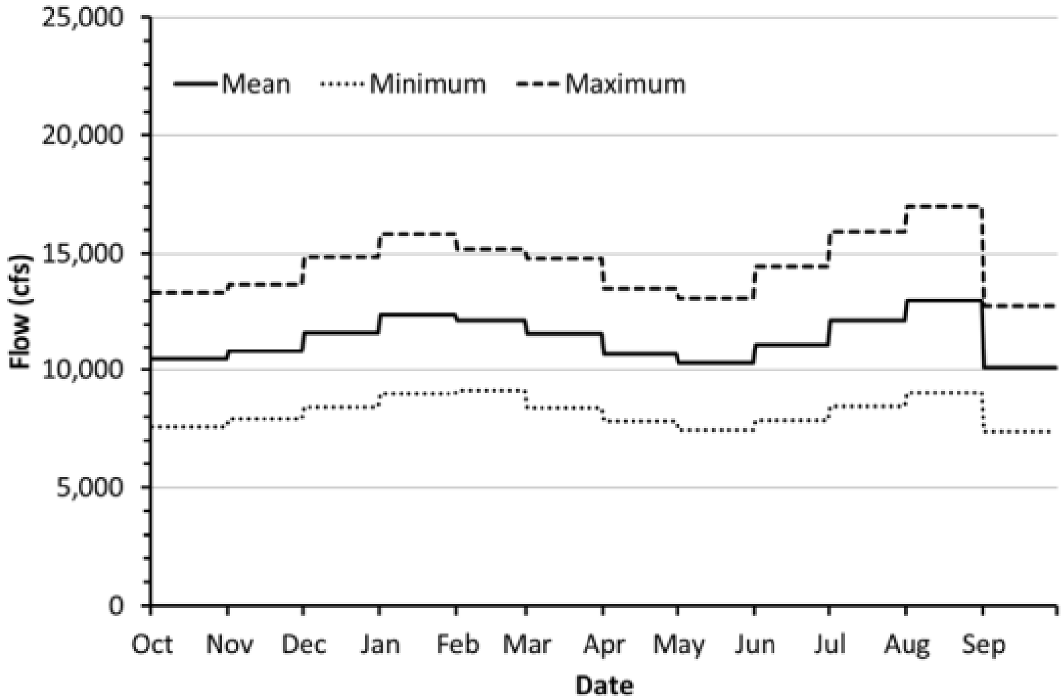
Hourly, daily, and monthly releases from Lake Powell for coordinated operations would be consistent with the parameters of the ROD for the LTEMP EIS (Reclamation and NPS 2016). Monthly releases from Glen Canyon Dam would be distributed proportionally across months for annual releases below 7.0 maf (see **Figure 2-3** for monthly distributions in a year when the annual release is 8.23 maf). If annual flows were adjusted mid-year, they would be distributed to meet the goals of the LTEMP, including potential distribution across monthly or experimental flow patterns, and including the unique resource considerations specific to any mid-year annual adjustments.

Table 2-6
Lake Powell Operational Tiers, Action Alternatives 1 and 2

Lake Powell Operational Tiers (subject to April adjustments or mid-year review modifications)		
Lake Powell Elevation (feet)	**Lake Powell Operational Tier**	**Lake Powell Active Storage*** (maf)
3,700		**23.31**
	Equalization Tier Equalize, avoid spills, or release 8.23 maf	
3,636–3,666	- - - - - - - - - - - - - - - - - -	**14.65–18.36**
(see Table 2.3-1 in the 2007 FEIS)	**Upper Elevation Balancing Tier** Release 8.23 maf; if Lake Mead <1,075 feet, balance contents with a minimum/maximum release of 7.0/9.0 maf	(2008–2026)
3,575	- - - - - - - - - - - - - - - - - -	**8.90**
	Lower Elevation Release Tier Set initial release: 6.0 maf; adjust releases based on the April Lake Powell end-of-water-year elevation projection: ≥3,575 feet, release 8.23 maf <3,575 feet AND ≥3,550 feet, release 7.48 maf <3,550 feet AND ≥3,525 feet, release 7.0 maf <3,525 feet AND ≥3,500 feet, maintain release of 6.0 maf	
3,500	<3,500 feet, then reduce releases (gains equals losses) such that Lake Powell ends the operating year at 3,500 feet	**4.22**
	- - - - - - - - - - - - - - - - - -	
	Protection Level <3,500 feet, in any month, reduce releases (gains equals losses) such that Lake Powell ends the operating year at 3,500 feet	
3,370		**0**

*Active storage values have been updated from 2007 based on the 2018 bathymetry.

Figure 2-3
Mean, Minimum, and Maximum Monthly Flows under LTEMP in an 8.23-maf Year



Hourly and daily releases would follow LTEMP parameters, so long as sufficient water is available from the annual release. If sufficient water is not available from the annual release to meet hourly and daily LTEMP release parameters, hourly and daily releases would follow the base operation daily and nightly minimum flows (8,000 cubic feet per second [cfs] and 5,000 cfs, respectively), for as long as possible. If sufficient water is not available from the annual release to support the base operation nightly minimum flow of 5,000 cfs, hourly and daily releases would be consistent with the run of the river[4] to match Lake Powell inflows consistent with protecting an elevation of 3,500 feet at Lake Powell.

Lower Elevation Release Tier

When the projected January 1 Lake Powell elevation is below 3,575 feet, an initial annual release in the amount of 6.0 maf would be set from Lake Powell. Adjustments to the annual release may then be made based on the April 24-Month Study, as outlined below.

- If the April 24-Month Study projects the end-of-water-year elevation to be at or above 3,575 feet, an adjustment would be made to release 8.23 maf from Lake Powell.
- If the April 24-Month Study projects the end-of-water-year elevation to be below 3,575 feet and at or above 3,550 feet, an adjustment would be made to release 7.48 maf from Lake Powell.

[4] In a general sense, "run of the river" means the inflow equals the outflow, adjusted for operational considerations, such as evaporation, seepage, and release capacity.

- If the April 24-Month Study projects the end-of-water-year elevation to be below 3,550 feet and at or above 3,525 feet, an adjustment would be made to release 7.0 maf from Lake Powell.
- If the April 24-Month Study projects the end-of-water-year elevation to be below 3,525 feet and at or above 3,500 feet, the release of 6.0 maf from Lake Powell would be maintained.
- If the April 24-Month Study projects the end-of-water-year elevation to be below 3,500 feet, the dam would be operated to maintain an elevation of at least 3,500 feet. Additionally, up to 6.0 maf would be released over the year with a goal of maintaining LTEMP minimum flows subject to run-of-the-river conditions, operational constraints, and prudent operations as determined by Reclamation.

Protection Level

If, in any month, Lake Powell's elevation is below 3,500 feet, the Lake Powell release would be set to maintain or increase the elevation with a maximum release of 6.0 maf; the goal would be to maintain LTEMP minimum flows subject to run-of-the-river conditions, operational constraints, and prudent operations as determined by Reclamation.

2.7.3 Implementation of Guidelines

The provisions for a mid-year review are the same as those under the No Action Alternative except revisions to shortages associated with Lake Mead elevation determinations in the mid-year review can be revised to allow for either further reduced deliveries or additional deliveries.

2.8 Action Alternative 2

This alternative describes a set of actions adopted pursuant to Secretarial authority under applicable federal law. Unlike current operations that were developed, and are being implemented, pursuant to basin-wide consensus (for example, the 2007 Interim Guidelines and the 2019 DCPs), Action Alternative 2 models changes to operations for both Glen Canyon Dam and Hoover Dam as developed by Reclamation. Action Alternative 2 models releases between 6.0 maf and 8.23 maf from Lake Powell when it is below 3,575 feet, with potentially lower releases to preserve an elevation of 3,500 feet and assumes additional inflow to Lake Powell pursuant to the 2019 DCPs.

Action Alternative 2 includes assumptions for reduced releases from Glen Canyon Dam and additional Lower Basin shortages that are not based exclusively on the concept of priority. While both the 2007 Interim Guidelines and the 2019 DCPs encompass reductions that reflect the priority system, the additional reductions identified in Action Alternative 2 for the remainder of the interim period would be distributed in the same percentage across all Lower Basin water users.[5] [6] Total additional shortage volumes for the Lower Basin are the same under Action Alternative 2 as under Action Alternative 1.

[5] Entities holding an entitlement to Mainstream water under (a) the Consolidated Decree, (b) a water delivery contract with the United States through the Secretary, or (c) a reservation of water by the Secretary.
[6] For example, if the additional shortage amount is 1 maf, the percentage of additional shortage volume is calculated by dividing 1 maf by 7.5 maf, which equals 13 percent. Then, a 13 percent additional reduction is modeled for each Lower Basin water user based on current water use.

As under Action Alternative 1, Action Alternative 2 models progressively larger Lower Basin reductions as Lake Mead's elevation declines and models larger Lower Basin reductions in 2025–2026 as compared with 2024. The total shortages and DCP contributions in 2024, as modeled, are limited to 2.083 maf; this is because this is the maximum volume analyzed in the 2007 FEIS. Working within this range of previously analyzed impacts will facilitate completing this SEIS process in the time available in advance of the 2024 operating year. Delaying operational decisions to perform additional analyses would not meet the express purpose of and need for this action.

This alternative includes actions and modeling assumptions that have precedent in actions previously undertaken by Reclamation under applicable federal law in both the Upper Basin (2021–2022) and Lower Basin (see the 1964 Determination by Secretary Udall to impose equivalent percentile reductions in light of reduced flows from Glen Canyon Dam). The goal is to operate Colorado River system reservoirs in a manner that ensures continued operations in a prudent manner throughout a range of projected future hydrologic conditions.

For all operations, including, but not limited to when Lake Powell is approaching 3,500 feet or when Lake Mead is approaching 950 feet, the Secretary reserves the right to operate Reclamation facilities to address extraordinary circumstances, as described in Section 7(D) of the 2007 Interim Guidelines, including "operations that are prudent or necessary for safety of dams, public health and safety, other emergency situations, or other unanticipated or unforeseen activities arising from actual operating experience."

2.8.1 Shortage Guidelines

As stated above, total additional shortage volumes for the Lower Basin are the same under Action Alternative 2 as under Action Alternative 1. The additional shortage volumes identified in **Table 2-3** and **Table 2-5** for calendar years 2024 and 2025–2026, respectively, would be achieved by a reduction of available Lower Basin annual consumptive use, distributed in the same percentage across all Lower Basin water users at the specified Lake Mead elevations. The distribution of reductions as modeled in Action Alternative 2 is based on each user's consumptively used water in 2021, as reported in Reclamation's final Colorado River Accounting and Water Use Report: Arizona, California, and Nevada prepared pursuant to Article V of the Supreme Court's Decree in *Arizona v. California* (as adjusted for conservation).

Table 2-7 displays the percentage of the additional shortage volumes at specified Lake Mead elevations and the distribution for each Lower Division State as modeled in Action Alternative 2. Reclamation may consider additional shortages in Shortage Condition Years 2025 and 2026 (see **Table 2-5**). This consideration would occur as part of the future analysis referenced in **Section 1.2** before the 2025 operating year operating condition determination.

Figure 2-2 shows a graphical view of Lower Basin shortages and contributions from the 2007 Interim Guidelines and 2019 DCPs plus additional shortages modeled under Action Alternative 2.

Like Action Alternative 1, whenever Lake Mead's content is projected to be below an elevation of 1,000 feet, based on the January 1 projection or a mid-year review, additional reductions may be needed to protect the minimum power pool (elevation 950 feet) and to reduce the risk of declining to dead pool (elevation 895 feet).

Table 2-7
2024 Lower Division States' Shortages and DCP Contributions by State, Action Alternative 2 (2024)

Lake Mead Elevation (feet)	2007 ROD Shortages + 2019 DCP Contributions (1,000 af)				2024 Additional Shortage* (1,000 af)					2024 Total Shortage + Contributions (1,000 af)			
	AZ	NV	CA	Total	Percentage Additional Reduction**	AZ	NV	CA	Total	AZ	NV	CA	Total
1,090 – >1,075	192	8	0	200	2.67%	75	8	117	200	267	16	117	400
1,075 – 1,050	512	21	0	533	7.11%	199	21	313	533	711	42	313	1,066
<1,050 – >1,045	592	25	0	617	8.23%	230	25	362	617	822	50	362	1,234
1,045 – >1,040	640	27	200	867	11.56%	324	35	509	867	964	62	709	1,734
1,040 – >1,035	640	27	250	917	15.55%	435	47	684	1,166	1,075	74	934	2,083
1,035 – >1,030	640	27	300	967	14.88%	417	45	655	1,116	1,057	72	955	2,083
1,030 – 1,025	640	27	350	1,017	14.21%	398	43	625	1,066	1,038	70	975	2,083
<1,025 – 1,000	720	30	350	1,100	13.11%	367	39	577	983	1,087	69	927	2,083
<1,000 – 975	720	30	350	1,100	13.11%	367	39	577	983	1,087	69	927	2,083
<975 – 950	720	30	350	1,100	13.11%	367	39	577	983	1,087	69	927	2,083
<950	720	30	350	1,100	13.11%	367	39	577	983	1,087	69	927	2,083

*The additional shortage volumes decrease at elevation 1,025 feet because the shortages under the 2007 Interim Guidelines increase by the same amount. Therefore, the additional shortage amounts necessary to get to the 2.083 maf total are lower.
**Percentage of 2021 consumptive use

2.8.2 Coordinated Reservoir Operations

The modifications to annual Lake Powell releases and operational tiers are the same as those under Action Alternative 1.

2.8.3 Implementation of Guidelines

The provisions for a mid-year review are the same as those under Action Alternative 1.

2.9 Alternatives Considered but Eliminated from Detailed Analysis

Reclamation received a number of submissions that represented commentors' intended operations of Colorado River reservoirs. Some submissions presented sufficient detail to potentially be considered as an action alternative. Others presented operational concepts (or components) that could potentially be used to develop a full action alternative. In either case, the following are described as "alternatives" that were brought forward during internal and public scoping. They were considered but eliminated from detailed analysis because they 1) would not fully meet the purpose and need (see **Section 1.3**); 2) are covered by the range of the action alternatives; or 3) are infeasible or inconsistent with the basic policy objectives for Colorado River operations, including consistency with applicable federal laws. In addition to the SEIS action alternatives, Reclamation is considering and analyzing other actions to improve dam operations separately from this SEIS. These actions are not discussed in this SEIS.

2.9.1 Fill Lake Powell First

Comments received during scoping proposed consideration of a recreation-based alternative that would prioritize filling Lake Powell to higher elevations, such as 3,588 feet, to serve recreational boating needs and to provide resulting benefits to mental health and local economic conditions. This alternative was not carried forward for detailed analysis because it does not meet the purpose, need, or objectives of the proposed action (which focuses on the critically low elevations impacting operations of both Glen Canyon and Hoover Dams during the interim period). It would not allow compliance with essential water delivery requirements, including the Law of the River and the 2007 Interim Guidelines. It also would not comply with other federal requirements and regulations, including the GCPA and the Lower Basin Drought Contingency Plan Agreement (2019).

Both the 2007 Interim Guidelines and the 2019 DCPs contemplate the need for additional measures to protect Lake Mead elevations. The DCPs added the commitment of participating Lower Basin DCP parties to "individual and collective action in the Lower Basin to avoid and protect against the potential for the elevation of Lake Mead to decline to elevations below 1,020 feet."

An alternative prioritizing recreation uses would not satisfy Reclamation's basic policy objectives and the requirements of the purpose of and need for Reclamation's action to protect both Glen Canyon Dam and Hoover Dam operations, system integrity, and public health and safety. It also would not comport with existing Colorado River law that governs allocation, appropriation, development, and exportation of the waters of the Basin. For these reasons, the alternative was not carried forward for detailed analysis.

2.9.2 Decommission Glen Canyon Dam or Operate for Run of the River

Comments received during scoping proposed either removing Glen Canyon Dam or leaving it in place while operating it to release only inflows or run of the river to further goals of new recreational activities; restoring the environmental, recreational, and cultural resources of the Grand Canyon and the Basin to their pre-dam conditions; and positively affecting the health of the Colorado River ecosystem.

This alternative would not meet the proposed action's purpose (which focuses on the critically low elevations impacting operations of both Glen Canyon and Hoover Dams during the interim period) and need (which is based on the potential that continued low-runoff conditions in the could lead Lake Powell and Lake Mead to decline to critically low elevations impacting operations in 2024). Congress authorized construction and operation of Glen Canyon Dam for specific purposes, and those congressional purposes cannot be met if the dam is decommissioned or not operated as designed. This proposed alternative, for example, would not allow compliance with water release requirements, including, but not limited to, the division and apportionment of the use of the waters of the Colorado River system under the Compact, as well as other portions of the Law of the River and 2007 Interim Guidelines.

This proposed alternative also would not comport with existing Colorado River law requiring that allocation, appropriation, development, and exportation of the waters of the Basin be consistent with Congress's clear direction to the Secretary to operate Glen Canyon Dam under the Law of the River. For these reasons, the alternative was not carried forward for detailed analysis.

2.9.3 Fill Lake Mead First

A counterpoint to the "Fill Lake Powell First" alternative discussed above, proponents of this alternative advocate for shifting primary water storage from Lake Powell to Lake Mead, using Lake Powell as a backup for seasonal and flood control purposes to meet the goals of reducing evaporation and seepage and increasing flexibility for implementing Grand Canyon restoration strategies.

This alternative would not meet the proposed action's purpose (which focuses on the critically low elevations impacting operations of both Glen Canyon and Hoover Dams during the interim period) and need (which is based on the potential that continued low-runoff conditions in the Basin could lead Lake Powell and Lake Mead to decline to critically low elevations impacting operations in 2024).

This proposed alternative, for example, would not allow compliance with water release requirements, including, but not limited to, the division and apportionment of the use of the waters of the Colorado River system under the Compact, as well as other portions of the Law of the River and 2007 Interim Guidelines. This alternative also would not comport with existing Colorado River law requiring that allocation, appropriation, development, and exportation of the waters of the Basin be consistent with Congress's clear direction to the Secretary to operate Glen Canyon Dam under the Law of the River. For these reasons, the alternative was not carried forward for detailed analysis.

2.9.4 One-Dam Alternative

Comments received during scoping proposed an alternative that prioritizes the preservation of one dam and reservoir (Hoover Dam/Lake Mead or Glen Canyon Dam/Lake Powell) over the other. Consistent with the reasons set forth in the above discussions of "Fill Lake Powell First" and "Fill Lake Mead First," this alternative was not carried forward for detailed analysis.

2.9.5 Evaporation, Seepage, and System Losses

Comments received during scoping, as well as the proposal submitted by six Basin States (Arizona, Colorado, Nevada, New Mexico, Utah, and Wyoming), proposed that Reclamation consider an alternative that apportions among all contractors reductions to account for water evaporation, seepage, and system losses.

While Reclamation has not carried forward an alternative that focuses explicitly on accounting for evaporation, seepage, and system losses, the alternatives considered in detail contemplate similar shortage amounts to those that would be assessed based on evaporation, seepage, and system loss calculations in the proposals received. However, the shortage amounts are implemented at different elevations and timing compared with the six Basin States proposal. The six Basin States proposal, which incorporates evaporation, seepage, and system losses, is analyzed further in **Appendix B**.

Reclamation anticipates publishing—separate from this SEIS process—an informational report in 2023 addressing potential methodologies to support assessments for evaporation, seepage, and other system losses in the Basin.

2.9.6 Ecosystem-Based Alternative

Comments received during scoping suggested that Reclamation design an alternative that maintains Colorado River flows and supports ecosystem needs. An ecosystem-based alternative would also include cuts to water allocations and implementing water conservation measures in the Lower Basin. Any operation would meet the applicable ecosystem-based requirements under applicable law.

This alternative was not carried forward for detailed analysis because it does not meet the proposed action's purpose, need, or objectives. This is because it does not focus on the critically low elevations impacting operations of both Glen Canyon and Hoover Dams during the interim period. Apart from concepts of beneficial-use determinations, Reclamation does not have the authority to mandate water conservation measures in the Lower Basin. The alternatives considered in detail do include additional shortages for the Lower Basin, as suggested by the proponents of this alternative.

2.9.7 Worst-Case Drought Alternative

Comments received during scoping suggested that Reclamation design an alternative that is responsive to worst-case drought modeling. Commenters expressed concern that the existing hydrology modeling does not represent the full range of potential drought scenarios and that an alternative is needed to address prolonged drought conditions. Comments requested updated baseflow modeling to reflect current conditions and to account for long-term climate modeling and worsening drought conditions.

Each action alternative analyzed in this SEIS acknowledges the possibility of operating Glen Canyon and Hoover Dams in a situation where the inflow minus losses equals outflow, subject to run-of-the-river conditions. This represents a worst-case scenario that would occur if elevations in Lake Powell or Lake Mead dropped below critically low levels approaching or reaching dead pool. The range of hydrologic modeling scenarios analyzed includes multiple hydrology sequences in which this type of operation would be necessary. The hydrologic modeling examines scenarios based on flows in the Basin over the past 30 years, which includes the driest 23-year period on record. To examine even worse drought conditions, the hydrologic modeling examines Basin flow scenarios with 90 percent and 80 percent of the flows seen over the past 30 years (up to a 20 percent reduction in flows compared with the last 30 years).

Reclamation believes this range of hydrology scenarios is an appropriate worst case to analyze for conditions that might occur between now and 2026, though longer-term trends could continue to worsen. Because the need for this action is to address the potential for continued low-runoff conditions in the Basin to lead Lake Powell and Lake Mead to decline to critically low elevations that would impact operations in 2024, and potentially in 2025 and 2026, an analysis of scenarios that are not reasonably foreseeable between 2024 and 2026 would not meet the purpose of and need for Reclamation's action.

2.9.8 Hydropower Prioritization Alternative

Comments suggested an alternative that includes elevation levels prioritizing preservation of the hydropower production and operations, and considers the contractual obligations for power delivery.

While Reclamation has not carried forward an alternative that focuses explicitly on prioritizing hydropower production, the alternatives considered in detail contemplate protection of critical reservoir levels, and the continued resulting water deliveries that accordingly also relate to the resulting ability to generate hydropower. An alternative prioritizing hydropower production over all other purposes—including water delivery—would not satisfy Reclamation's basic policy objectives. It also would not satisfy the requirements of the purpose of and need for Reclamation's action to protect both Glen Canyon and Hoover Dam operations, system integrity, and public health and safety. This would also need to be assessed for consistency with governing authorities. Finally, inclusion of similar protection elevations in the alternatives considered in detail provides adequate opportunity for analysis.

2.9.9 Importation of Water

Reclamation received a number of proposals calling for the importation of water (for example, desalinizing and importing water from the Pacific Ocean). These are not considered in detail in this SEIS because the proposals received did not contain sufficient detail to analyze them. Also, they are not actionable during the interim period (before January 1, 2027). Therefore, they do not meet the purpose of and need for Reclamation's action.

2.10 Summary Comparison of Alternatives

Summary comparisons of the alternatives identified and analyzed in the SEIS are provided in **Table 2-8** as a matrix of alternatives and their approach for addressing each of the four sections of the 2007 Interim Guidelines (73 *Federal Register* 19881, April 11, 2008) identified in the NOI to prepare this SEIS (87 *Federal Register* 69042, November 17, 2022). **Table 2-9** provides a comparison of the shortage guidelines elements of the alternatives (Section 2. Determination of Lake Mead Operation during the Interim Period). **Table 2-10** provides a comparison of the coordinated reservoir operations elements of the alternatives (Section 6. Coordinated Operation of Lake Powell and Lake Mead during the Interim Period).

Table 2-8
Comparison of Alternatives

Alternative	**Shortage Guidelines** (Section 2. Determination of Lake Mead Operation during the Interim Period)	**Coordinated Reservoir Operations** (Section 6. Coordinated Operation of Lake Powell and Lake Mead during the Interim Period)	**Implementation of Guidelines** (Section 7. Implementation of Guidelines)
No Action Alternative	• Shortages from Lake Mead (that is, reduced deliveries to Lower Basin water users) and DCP contributions of 200,000 af at 1,090 feet to 1.1 maf below 1,025 feet • Shortages are distributed across Lower Basin water users according to priority.	• Below 3,575 feet at Lake Powell, either reduce Lake Powell releases or balance volumes depending on elevations at Lake Powell and Lake Mead.	• Mid-year review may adjust the Lake Powell operational tier up or down or reduce shortages from Lake Mead (allow additional deliveries to Lower Basin water users).
Action Alternative 1	• 2024 shortages from Lake Mead and DCP contributions of 400,000 af at 1,090 feet to 2.083 maf at or below 1,040 feet • 2025–2026 shortages from Lake Mead and DCP contributions of 400,000 af at 1,090 feet to 4.000 maf below 950 feet • Shortages are distributed across Lower Basin water users according to priority.	• Below 3,575 feet at Lake Powell, set initial release at 6.0 maf and adjust to as high as 8.23 maf based on the April end-of-water-year elevation projection. • Below 3,500 feet at Lake Powell in any month, reduce releases (gains equals losses) such that Lake Powell ends the operating year at 3,500 feet.	• Mid-year review may adjust the Lake Powell operational tier up or down or reduce or increase shortages from Lake Mead (allow additional or reduced deliveries to Lower Basin water users).
Action Alternative 2	• Total shortages and DCP contributions for Lower Basin water users are the same as under Action Alternative 1. • Shortages are distributed in the same percentage across all Lower Basin water users.	• Same as Action Alternative 1	• Same as Action Alternative 1

Table 2-9
Comparison of Shortage Guidelines by Alternative (volumes in 1,000 af)*

Lake Mead Elevation (feet)	**No Action Alternative (Total Shortages and DCP Contributions)**	**Action Alternatives 1 and 2 (Total Shortages and DCP Contributions 2024 / 2025–2026)**
1,090 – >1,075	200	400 / *400*
1,075 – 1,050	533	1,066 / *1,066*
<1,050 – >1,045	617	1,234 / *1,234*
1,045 – >1,040	867	1,734 / *1,734*
1,040 – >1,035	917	2,083 / *2,083*
1,035 – >1,030	967	2,083 / *2,250*
1,030 – 1,025	1,017	2,083 / *2,500*
<1,025 – 1,000	1,100	2,083 / *3,000*
<1,000 – 975	1,100	2,083 / *3,333*
<975 – 950	1,100	2,083 / *3,667*
<950	1,100	2,083 / *4,000*

* This table only shows combined Lower Division State shortage volumes and DCP contributions. In addition to the volumes shown in this table, the analysis for each alternative includes water delivery reductions to Mexico under low-elevation reservoir conditions and Mexico's savings that contribute to the Binational Water Scarcity Contingency Plan in accordance with Minute 323 to the 1944 Water Treaty.

Table 2-10
Comparison of Coordinated Reservoir Operations by Alternative

Lake Powell Elevation (feet)	**No Action Alternative**	**Action Alternatives 1 and 2**	**Lake Powell Active Storage** (maf)*
3,700	**Equalization Tier** Equalize, avoid spills, or release 8.23 maf	**Equalization Tier** Equalize, avoid spills, or release 8.23 maf	**23.31**
3,636–3,666 (see Table 2.3-1 in the 2007 FEIS)	**Upper Elevation Balancing Tier** Release 8.23 maf; if Lake Mead <1,075 feet, balance contents with a minimum/maximum release of 7.0/9.0 maf	**Upper Elevation Balancing Tier** Release 8.23 maf; if Lake Mead <1,075 feet, balance contents with a minimum/maximum release of 7.0/9.0 maf	**14.65–18.36** (2008–2026)
3,575	**Mid-Elevation Release Tier** Release 7.48 maf; if Lake Mead <1,025 feet, release 8.23 maf	**Lower Elevation Release Tier** Set initial release: 6.0 maf; adjust releases based on April Lake Powell end-of-water-year elevation projection: ≥3,575 feet, release 8.23 maf <3,575 feet AND ≥3,550 feet, release 7.48 maf <3,550 feet AND ≥3,525 feet, release 7.0 maf <3,525 feet AND ≥3,500 feet, maintain release of 6.0 maf <3,500 feet, then reduce releases (gains equals losses) such that Lake Powell ends the operating year at 3,500 feet	**8.90**
3,525	**Lower Elevation Balancing Tier** Balance contents with a minimum/maximum release of 7.0/9.5 maf		**5.55**
3,500		**Protection Level** <3,500 feet in any month, reduce releases (gains equals losses) such that Lake Powell ends the operating year at 3,500 feet	**4.22**
3,370			**0**

*Active storage values have been updated from 2007 based on the 2018 bathymetry.

2.11 Summary of Potential Effects

Table 2-11 presents a summary of the potential effects of the alternatives. **Chapter 3**, Affected Environment and Environmental Consequences, contains detailed descriptions of these effects.

Table 2-11
Summary of Potential Effects of the Alternatives

SEIS Section	Affected Resource	Alternatives		
		No Action	**Action Alternative 1**	**Action Alternative 2**
3.6	**Hydrologic Resources**			
	Reservoir elevations for Lake Powell	There is a higher likelihood of monthly pool elevations dropping below the critical elevation of 3,490 feet than under either of the two action alternatives. Modeled end-of-water-year pool elevations result in lower median and wider range of values than the action alternatives. This suggests the lack of the ability to recover reservoir elevations above critical elevations once they are reached.	The operational modification designed to protect a Lake Powell elevation of 3,500 feet is effective at minimizing instances of falling below 3,490 feet in 2024 and eliminating this outcome for all modeled traces by 2026. The median monthly elevation of Lake Powell for the action alternatives remains higher than the No Action Alternative through 2026.	Same impact as Action Alternative 1 with a minor variation in model traces due to assumptions for potential DROA contributions.
	Reservoir elevations for Lake Mead	In 2026, 7 percent of traces under the No Action Alternative approached dead pool, and the reservoir does not recover for the rest of the period of analysis.	In 2024, there would initially be lower Lake Mead elevations than under the No Action Alternative. One percent of traces reach dead pool in April 2025 before recovering for the next 10 months.	In 2024, there would initially be lower Lake Mead elevations than under the No Action Alternative. One percent of traces reach dead pool for 3 months in 2026, and then elevations recover.

SEIS Section	Affected Resource	Alternatives		
		No Action	Action Alternative 1	Action Alternative 2
3.6 *(cont.)*	Reservoir releases for Glen Canyon Dam (at Lake Powell)	Median annual releases for the No Action Alternative increase from 2024 to 2026. Median annual releases for the No Action Alternative are higher than for the action alternatives with less variability, except in 2026. During the driest 25 percent of traces, the No Action Alternative releases continue to be larger than the action alternatives' releases, resulting in decreasing Lake Powell elevations.	The new Lower Elevation Release Tier results in lower (median) monthly releases for the first half of the water year and then higher (median) monthly releases for April through September, as compared with the No Action Alternative. Median annual releases increase from 2024 to 2026. During the driest 25 percent of traces, Action Alternatives 1 and 2 have lower and more variable releases than the No Action Alternative.	There would be similar impacts as under Action Alternative 1 with minor variations in model traces. For example, Action Alternative 2 has higher releases in some model traces due to assumptions for potential DROA contributions.
	Reservoir releases for Hoover Dam (at Lake Mead)	Median annual releases for the No Action Alternative decrease slightly from 2024 to 2026. The median annual releases are higher than under the action alternatives with less variability, except for 2026 when 5 percent of No Action Alternative model traces are associated with dead pool elevations.	Median annual releases are lower than under the No Action Alternative and are more variable. Median annual releases decrease in 2025 and begin to recover in 2026.	There would be the same impact as described under Action Alternative 1 with a minor variation in model traces due to assumptions for potential DROA contributions.
	River flows	River flows for all alternatives decline over time. Flows under the No Action Alternative decline at a slower rate than the action alternatives and have less variation.	River flows for the various reaches are lower than they would be under the No Action Alternative with a wider variation of possible flows based on the model traces. Median annual river flows are typically the lowest in 2025 and recover slightly in 2026.	There would be the same impact as under Action Alternative 1 with a minor variation in model traces due to assumptions for potential DROA contributions.
	Groundwater	Certain portions of the river are anticipated to have decreased groundwater elevations due to decreasing river flows and shallower river stages.	Groundwater elevations are anticipated to decrease more than they would under the No Action Alternative due to lower river flows.	There would be the same impacts as under Action Alternative 1.

SEIS Section	Affected Resource	Alternatives		
		No Action	Action Alternative 1	Action Alternative 2
3.7	**Water Deliveries**			
	Apportionments in the Upper Division States	No impact.	No impact.	No impact.
	Apportionments and water entitlements to and within the Lower Division States	No impact.	No impact.	No impact.
	Lower Division State water supply determinations	Initially, there would be fewer impacts; however, there would be increased combined shortages, DCP contributions, and impacts on water supply determinations as reservoir levels decrease.	Initially, there would be greater impacts from increased combined shortages and DCP contributions; however, impacts would decrease over time as Lake Mead's elevation stabilizes and increases over time. There would be greater impacts on Arizona and Nevada and fewer on California relative to Action Alternative 2.	There would be similar combined impacts on Lower Division States as under Action Alternative 1; however, there would be greater impacts on California and fewer impacts on Arizona and Nevada relative to Action Alternative 1.
	Total water deliveries to Lower Division States	Initially, there would be fewer impacts; however, there would be increased impacts on deliveries as reservoir levels decrease and greater frequency of system shortages occurs.	Initially, there would be greater impacts, but impacts decrease over time as Lake Mead's elevations stabilize and system shortages are reduced, relative to the No Action Alternative. There would be greater impacts on Arizona and Nevada and fewer impacts on California, relative to Action Alternative 2.	There would be similar impacts on combined Lower Division States as under Action Alternative 1; however, there would be greater impacts on California and fewer impacts on Arizona and Nevada, relative to Action Alternative 1.

SEIS Section	Affected Resource	Alternatives		
		No Action	**Action Alternative 1**	**Action Alternative 2**
3.7 *(cont.)*	Deliveries to Mexico	This SEIS does not consider actions for Mexico. There would be no change to specified reductions and recoverable savings to Mexico. Impacts on modeled reductions and recoverable savings to Mexico are possible as Lake Mead elevations decline and if dead pool is reached.	This SEIS does not consider actions for Mexico. There would be no change to specified reductions and recoverable savings to Mexico. Impacts on modeled reductions and recoverable savings to Mexico are possible as Lake Mead elevations decline and if dead pool is reached. Initially, there would be greater impacts on modeled deliveries, then decreased impacts as Lake Mead elevations stabilize and increase.	This SEIS does not consider actions for Mexico. Same impacts as Action Alternative 1.
	Modeled distribution of shortages to and within the Lower Division States	Initially, there would be fewer impacts but increased impacts on shortages as reservoir levels decrease. As total shortages analyzed increase, there would be a corresponding increase in shortages allocated to Arizona 4th-priority entitlement holders, Nevada eighth-priority level users, and California DCP contributions.	As total shortages increase, there would be a corresponding increase in shortages allocated to Arizona 4th-priority entitlement holders and Nevada 8th-priority contractors. California would continue to make DCP contributions but would not be affected by additional shortages.	There would be similar impacts on combined Lower Division States as under Action Alternative 1; however, due to additional shortages, there would be greater impacts on California and fewer impacts on Arizona and Nevada, relative to Action Alternative 1.
3.8	**Water Quality**			
	Salinity	Higher lake levels result in marginally lower salinity concentrations. Under the No Action Alternative, Lake Powell is much more likely to reach dead pool (3,370 feet). If Lake Powell were to reach dead pool, it would lead to an increase in salinity.	Higher lake levels result in marginally lower salinity concentrations.	Same impact as under Action Alternative 1.

SEIS Section	Affected Resource	Alternatives		
		No Action	Action Alternative 1	Action Alternative 2
3.8 *(cont.)*	Temperature	There are slightly lower probabilities of exceeding 16°C and much lower probabilities of exceeding 20°C than under the action alternatives. Release temperatures are coldest when reservoir elevations are highest. This may result in lower temperatures. However, under this alternative, Lake Powell is much more likely to reach dead pool, which would lead to a large increase in temperatures.	There are slightly higher probabilities of exceeding 16°C and much higher probabilities of exceeding 20°C than under the No Action Alternative. Release temperatures are coldest when reservoir elevations are highest.	Same as Action Alternative 1.
	Sediment	Sediment dredging projects in the reach below Hoover Dam would continue to ensure water deliveries to downstream users. In the Marble and Grand Canyons, spring HFEs would only be triggered for approximately 15 percent of the time, and fall HFEs would be triggered approximately 70 percent of the time, each year between 2024 and 2026. If Lake Powell drops below 3,500 feet, HFEs are infeasible. Sand deposition would be insufficient to build sandbars. Sandbars would progressively erode from current conditions and through 2026.	Same as the No Action Alternative, except this alternative would reduce the potential of elevations below the Protection Level (below 3,500 feet). This increases the probability of HFE implementation, compared with the No Action Alternative.	Same as Action Alternative 1.
	Nutrients and algae	Lake Powell would be more likely to reach dead pool, which would raise temperatures and opportunities for algal growth. Bypass only scenarios would also likely result in more algal growth.	Slightly higher temperatures would provide more opportunities for algal growth. An increased probability of low DO would create more bioavailable phosphorus, which may provide more opportunities for algal growth.	Same as Action Alternative 1.

SEIS Section	Affected Resource	Alternatives		
		No Action	Action Alternative 1	Action Alternative 2
3.8 *(cont.)*	Dissolved oxygen	The releases from Glen Canyon Dam mean it would be less probable for the August–October DO levels to drop below 5mg/L, compared with under the action alternatives. The use of river outlet works aerates releases. Lake Powell is more likely to reach dead pool under the No Action Alternative.	The releases from Glen Canyon Dam mean it would be more probable for August–October DO levels to drop below 5mg/L, compared with under the No Action Alternative.	Same as Action Alternative 1.
	Metals	The No Action Alternative would be unlikely to reduce dilution capacity significantly. Lake Powell would be more likely to reach dead pool, which may affect metals' concentrations as elevations would continue to decrease.	Action Alternative 1 would be unlikely to reduce dilution capacity significantly.	Same as Action Alternative 1.
3.9	**Air Quality**			
	Shoreline exposure fugitive dust	Increased shoreline exposure would result in a potential increase of dust and particulate matter. Under the No Action Alternative, Lake Powell and Lake Mead would have the most acreage of exposed shoreline and therefore the most potential for increased fugitive dust emissions.	Shoreline exposure is anticipated to decrease compared with the No Action Alternative.	Similar to Action Alternative 1, with the potential for even less shoreline exposure due to potential DROA releases.
	Alternative power associated with greenhouse gases	The necessity for alternative power (coal and natural gas) results in an increase of greenhouse gases. Under the No Action Alternative, there is the most potential for alternative power and therefore the most potential for increased greenhouse gas emissions.	Hydropower is anticipated to increase compared with under the No Action Alternative.	Same as Action Alternative 1.

SEIS Section	Affected Resource	Alternatives		
		No Action	Action Alternative 1	Action Alternative 2
3.10	**Visual Resources**			
	Visibility of attraction features	Cathedral in the Desert would be visible and accessible. More of the upstream side of Glen Canyon and Hoover Dams would be visible.	Impacts would be similar to those under the No Action Alternative, except less of the upstream side of Glen Canyon and Hoover Dams would be visible.	Same as Action Alternative 1.
	Lake Powell maximum height of calcium carbonate ring, 10th percentile, 2025	204 feet	200 feet	158 feet
	Lake Mead maximum height of calcium carbonate ring, 10th percentile, 2025	233 feet	224 feet	220 feet
	Colorado River landscape character	Initially, there would be less impacts; however, if Lake Powell reaches dead pool, impacts would be extensive and immediate.	Lower releases would result in increased initial impacts; however, based on protecting 3,500 feet, this alternative would temper the more extensive impacts associated with the No Action Alternative by maintaining consistent flows along the Colorado River.	The impacts would be similar to those under Action Alternative 1, except based on potential releases from Upper Basin reservoirs, this alternative would result in decreased impacts on the landscape character.
	Lower Division States' landscape character	Initially, there would be lower impacts; however, if Lake Mead reaches dead pool, dramatic decreases in water availability could affect the landscape character in all three Lower Division States.	Based on water supply adjustments to temper impacts, initial shortages would be focused within Arizona and Nevada with shortages identified for California if Lake Powell drops below 1,040 feet.	The impacts would be similar to those under Action Alternative 1, except water shortages would be distributed across all three Lower Division States. This would result in more widely distributed, but less intense, impacts on the landscape character.

SEIS Section	Affected Resource	Alternatives		
		No Action	Action Alternative 1	Action Alternative 2
3.11	**Cultural Resources**			
	Low lake elevations exposing cultural resources	Low lake levels at Lake Mead and Lake Powell would expose resources to increased wave action, wet/dry cycling, and visitation.	Projected higher lake levels would expose fewer resources.	Same as Action Alternative 1.
	Low river levels exposing cultural resources	Low river levels would expose more resources to visitation, but they would increase available sediment for wind transport to protect some resources.	Projected higher river levels would expose fewer resources, but they would make less sediment available for wind transport to protect some resources.	Same as Action Alternative 1.
	Alterations to traditional cultural places	Visitation to archaeological sites may increase as resources are exposed. Plant habitat would increase for nonnative species and decrease for native species.	Projected higher river levels would expose less sites, and there would be a decline in nonnative plant species.	Same as Action Alternative 1.
3.12	**Paleontological Resources**			
	Lower lake levels exposing paleontological resources	Very low lake levels at Lake Mead and Lake Powell would expose paleontological resources to increased wave action, erosion, wet/dry cycling, visitation, and unauthorized collecting	Projected higher lake levels would expose fewer paleontological resources to potential impacts from wave action, erosion, wet/dry cycling, visitation, and unauthorized collecting.	Same as Action Alternative 1.
	Lower river levels exposing paleontological resources	Lower river levels would expose more resources to visitation and unauthorized collecting, but potentially increase available sediment for wind transport to protect some resources.	Projected higher river levels would expose fewer resources, but they may make less sediment available for wind transport to protect some resources.	Same as Action Alternative 1.

SEIS Section	Affected Resource	Alternatives		
		No Action	Action Alternative 1	Action Alternative 2
3.13	**Biological Resources**			
	Vegetation	Water elevations are predicted to decrease over time, resulting in short-term changes to riparian vegetation, including an increase of invasive plant species and loss of suitable habitat for native plant species.	At Lake Powell and Lake Mead, fewer acres have the potential to be invaded by nonnative species, as compared with under the No Action Alternative. Impacts on riparian vegetation would be greater as compared with the No Action Alternative, as water flows are reduced to maintain higher water elevations in Lake Powell and Lake Mead.	Same as Action Alternative 1.
	Wildlife	Water elevations are predicted to decrease over time with the potential to reach dead pool in Lake Mead, This would result in impacts on wildlife from decreased flows and the reduction of lake levels.	There would be similar impacts as those described under the No Action Alternative, with a lesser magnitude due to contingencies in place to protect elevations at Lake Mead and ensure flowing water in all sections.	Same as Action Alternative 1.
	Special status species	Water elevations are predicted to decrease over time with the potential to reach dead pool in Lake Mead. This would result in impacts on special status species from decreased flows and the reduction of lake levels.	There would be similar impacts as those described under the No Action Alternative, with a lesser magnitude due to contingencies in place to protect elevations at Lake Mead and ensure flowing water in all sections.	Same as Action Alternative 1.

SEIS Section	Affected Resource	Alternatives		
		No Action	Action Alternative 1	Action Alternative 2
3.14	**Recreation**			
	Recreation at Lake Powell	Projected Lake Powell elevations would be below the critical thresholds for most boat launch facilities, resulting in a reduction in the quality of or the loss of reservoir boating opportunities on Lake Powell. Dock access would be unavailable from the Rainbow Bridge National Monument shoreline. Declining pool elevations would expose additional areas of Glen Canyon, creating new visitation patterns and resource protection challenges. Sport fish populations are not expected to be impacted.	There would be similar impacts as those described under the No Action Alternative, with a lesser magnitude due to Action Alternative 1 preserving more water in Lake Powell and reducing overall variability in water surface elevations.	Same as Action Alternative 1.
	Recreation from Glen Canyon Dam to Lake Mead	Daytime flows would not drop lower than the safe whitewater boating threshold of 5,000 cfs. Lethal limits for rainbow trout are not projected to be exceeded in any month. If Lake Powell were to reach dead pool beyond 2026, it would lead to a large increase in water temperature, which would lead to potentially lethal conditions for rainbow trout.	There would be similar impacts on whitewater boating as described under the No Action Alternative. Predicted release temperatures have higher temperature magnitudes than under the No Action Alternative, which could result in a greater likelihood that temperatures would reach or exceed the 23°C threshold at which rainbow trout stop growing. However, Action Alternative 1 would reduce water temperatures beyond 2026 compared with the No Action Alternative, thereby benefiting rainbow trout.	Same as Action Alternative 1.

SEIS Section	Affected Resource	Alternatives		
		No Action	Action Alternative 1	Action Alternative 2
3.14 *(cont.)*	Recreation at Lake Mead	The projected Lake Mead elevation is below the critical threshold for all boat launch facilities except the Pearce Ferry Road launch ramp, which would necessitate boat launch facilities be closed or relocated. The projected median pool elevation for Lake Mead would likely result in boaters encountering boating navigational hazards. Projected surface water temperatures would not be anticipated to impact sport fish.	There would be similar impacts as those described under the No Action Alternative; however, the slight rebound in Lake Mead pool elevations under Action Alternative 1 could marginally help limit the closure or relocation of boat launch facilities in 2026.	Same as Action Alternative 1.
	Recreation from Hoover Dam to SIB	Flow releases from Hoover Dam, Davis Dam, Parker Dam, and Imperial Dam would be within the historical operating range; therefore, there would be minimal changes in exposure to boating navigation hazards caused by changes in the river elevation or velocity, changes in access or use of rest areas and take-out points, changes in trip duration caused by changes in river velocity, or decreases in access or use of sport fishing sites caused by changes in flows. The minor changes in water temperatures that may occur downstream of Hoover Dam would not be expected to affect warmwater sport fish.	Same as the No Action Alternative.	Same as the No Action Alternative.
3.15	**Electrical Power Resources**			
	Glen Canyon Powerplant			
	Average annual generation	2,192,899 MWh	+1,433,796 MWh	+1,528,935 MWh
	Average August capacity	394 MW	+96 MW	+117 MW
	Average annual total hydropower value	$469,595,000	+$117,442,000	+$124,769,000

SEIS Section	Affected Resource	Alternatives		
		No Action	Action Alternative 1	Action Alternative 2
3.15 *(cont.)*	*Hoover Powerplant*			
	Average annual generation	2,459,590 MWh	-623,173 MWh	-598,550 MWh
	Average August capacity	868 MW	+33 MW	+36 MW
	Average annual total hydropower value	$976,746,000	$909,310,000	$913,140,000
	Parker and Davis Powerplants			
	Average annual generation	1,427,805 MWh	-388,284 MWh	-448,560 MWh
	Average August capacity	Negligible impacts on the Parker and Davis Powerplants	Negligible impacts on the Parker and Davis Powerplants	Negligible impacts on the Parker and Davis Powerplants
	Average annual total hydropower value	$433,953,000	$393,953,000	$386,271,000
	Changes in the total hydropower value impact on the various power funds	Reduced total hydropower value at Glen Canyon Powerplant would result in reduced contributions to the Basin Fund. Reduced total hydropower value at Hoover, Parker, and Davis Powerplants would result in reduced contributions to the Development Fund. Continued revenue from surcharges at Hoover, Parker, and Davis Powerplants would result in minor impacts on the Dam Fund.	Continued positive total hydropower value would result in continued contributions to the Basin Fund. Reduced total hydropower value at Hoover, Parker, and Davis Powerplants would result in reduced contributions to the Development Fund. Continued revenue from surcharges at Hoover, Parker, and Davis Powerplants would result in minor impacts on the Dam Fund.	Same as Action Alternative 1 with slightly higher contributions to the Basin Fund and Development Fund. Same as Action Alternative 1 for the Dam Fund.
	The basin funds' impacts on other governmental programs	Reduced cash in the Basin Fund and Development Fund would result in less contributions to associated government programs. Continued financial resources in the Dam Fund would have minor impacts on the associated government programs.	Continued financial resources in the Basin Fund would result in continued contributions to associated government programs. Reduced cash in the Development Fund would result in less contributions to the associated programs. Continued financial resources in the Dam Fund would have minor impacts on the associated programs.	Same as Action Alternative 1 with slightly higher contributions to the government programs associated with the Basin Fund and Development Fund. Same as Action Alternative 1 for government programs associated with the Dam Fund.

SEIS Section	Affected Resource	Alternatives		
		No Action	Action Alternative 1	Action Alternative 2
3.16	**Socioeconomics**			
	Loss of agricultural production and associated jobs, income, and tax revenue for Indian and non-Indian agriculture in Arizona, California, and Nevada from 2024 through 2026	Arizona: Production: $100–$116 million loss Jobs: 657–1,613 lost Income: $60–$108 million loss Tax revenue: $10–$23 million loss California: No impacts Nevada: No impacts	Arizona: Production: $82–$257 million loss Jobs: 1,060– 7,078 lost Income: $87–$452 million loss Tax revenue: $15–$92 million loss California: Production: $0–$486 million loss Jobs: 0–2,924 lost Income: $0–$185 million loss Tax revenue: $0–$66 million loss Nevada: No impacts	Arizona: Production: $79–$264 million loss Jobs: 889–4,410 lost Income: $81–$290 million loss Tax revenue: $15–$50 million loss California: Production: $23–$338 million loss Jobs: 110–2,439 lost Income: $9–$165 million loss Tax revenue: $3–$60 million loss Nevada: Production: $23,000–$316,000 loss
	Recreation economic contributions	Economic contributions from recreation in Lake Powell and Lake Mead, river-based recreation, and adjacent land-based recreation would continue. Due to anticipated reservoir levels, there is the potential for reduced contributions from reservoir-based recreation due to inaccessibility of boat launches in Lakes Powell and Mead as well as navigational issues. Economic contributions from commercial whitewater rafting would be supported under all alternatives due to minimum flow requirements; however, the recreational experience would be impacted by the variation in flow	There would be the continued potential for a decrease in economic contributions from water-based recreation, similar to under the No Action Alternative. Impacts on water-based recreation economic contributions may be moderated by a reduction on the overall variability in water elevation in the long term.	Same as Action Alternative 1.

SEIS Section	Affected Resource	Alternatives		
		No Action	**Action Alternative 1**	**Action Alternative 2**
3.16 *(cont.)*	Municipal and industrial water social and economic contributions	Under all alternatives, allocated water shortages for different water elevations in Lake Mead would result in higher domestic water shortages compared with 2021 use levels. The specific economic impacts from domestic and industrial water shortages are unknown due to the variety of approaches municipalities and other entitlement holders utilize in shortage scenarios, including supply-side actions (such as groundwater recharge, water purchase agreements, and alternative water supplies) and demand-side strategies (such as water conservation measures). Under the No Action Alternative, impacts would be realized at lower shortage scenarios for Arizona long-term contractors (533,000-af scenario) and Nevada entitlement holders (200,000-af scenario) compared with California; this is due to the modeled effects of the priority system in the 2007 FEIS. At a 1.100-maf shortage scenario, maximum levels of shortage would result in domestic water shortages of 178,590 af in Arizona, 30,000 af in Nevada, and 350,000 af in California (pursuant to the DCPs).	Under Action Alternative 1, impacts would be realized at the lowest shortage level (400,000-af scenario) for Arizona and Nevada entitlement holders, while California would experience impacts starting at the 2.083-maf scenario. The lowest levels of shortage (at which the respective state would begin to experience impacts) would result in domestic water shortages of 58,316 af in Arizona, 16,000 af in Nevada, and 261,593 af in California. The maximum levels of shortage (4.000-maf shortage scenario) would result in domestic water shortages of 741,409 af in Arizona, 160,000 af in Nevada, and 843,052 af in California.	Under Action Alternative 2, impacts would be realized at all shortage scenarios for all three states. The lowest levels of shortage would result in domestic water shortages of 1,402 af in Arizona, 15,919 af in Nevada, and 25,827 af in California. The maximum levels of shortage (4.000-maf shortage scenario) would result in domestic water shortages of 603,284 af in Arizona, 144,825 af in Nevada, and 724,491 af in California.

SEIS Section	Affected Resource	Alternatives		
		No Action	Action Alternative 1	Action Alternative 2
3.17	**Environmental Justice**			
	Environmental justice communities	Initially, there would be fewer impacts; however, there would be an increased potential of disproportionate impacts on environmental justice communities as reservoir levels decrease. The available water supply would be reduced to zero for some Arizona priorities (all 5th- and 6th-priority contracts, CAP agricultural, and other excess) located within the following Arizona environmental justice study area counties: Pinal and Pima; this includes two Tribes.	The available water supply would be reduced for the same priorities as under the No Action Alternative and additional Arizona priorities located within the following Arizona environmental justice study area counties: Coconino, Gila, La Paz, Mohave, Pima, Pinal, and Yuma' this includes eight Tribes. Potential disproportionate impacts on environmental justice communities would be more concentrated and severe compared with under the No Action Alternative.	Compared with Action Alternative 1, the available water supply would be reduced to zero for the same water users within the following Arizona environmental justice study area counties: Pinal and Pima; this includes two Tribes. There would be the potential for disproportionate impacts on a range of users within environmental justice communities; however, impacts would be less concentrated and severe, compared with Action Alternative 1.
3.18	**Indian Trust Assets**			
	Water rights and allocations	Tribal water rights are a matter of settled law; however, annual water deliveries may change as a result of shortages. Water deliveries and shortages would be shared based on priority.	Impacts would be similar to those under the No Action Alternative. The number of Tribes affected (and how they are affected) varies because water deliveries are based on priority. However, long-term water deliveries are projected to be more reliable as compared with the No Action Alternative.	The number of Tribes affected (and how they are affected) varies because additional shortages are distributed based on the same percentage for all water users. However, long-term water deliveries are projected to be more reliable as compared with the No Action Alternative.
	Cultural and biological resources	Low river levels would expose more resources to visitation. As water elevations decrease, there would be short-term changes to riparian vegetation, including an increase of invasive plant species and the loss of suitable habitat for native plant species.	Projected higher river levels would expose less sites, and there would be a decline in nonnative plant species.	Same as Action Alternative 1.

Chapter 3. Affected Environment and Environmental Consequences

3.1 Introduction

This chapter describes the affected environment and environmental consequences for the resources that could be significantly affected by the alternatives as described in **Table 1-1**. The affected environment sections describe and update the current conditions, focusing on those that have changed since 2007. The environmental consequences sections provide analysis of the No Action Alternative and Action Alternatives 1 and 2, as described in **Chapter 2**. The analysis is issue-based, meaning it addresses the specific relevant concerns identified during scoping for a particular resource. For brevity and to avoid redundancy, the 2007 FEIS (Reclamation 2007) is incorporated by reference.

The methodology and technical assumptions used to analyze the potential impacts on the Colorado River system (such as reservoir elevations, releases, and flows) are described in **Section 3.3**. Additional methodologies and assumptions used to analyze specific resources are described in the appropriate resource section of **Chapter 3**.

3.2 Geographic and Temporal Scope

Like the 2007 FEIS, the SEIS's geographic scope of analysis (also termed study or analysis area) is the Colorado River corridor from the full pool elevation of Lake Powell to the f (see Map 3.2-1 in the 2007 FEIS). For some resources, the impact analysis area differs from this scope to account for the impacts on that specific resource; when different, the impact analysis area is defined in the resource's specific methodology section. Additionally, reservoirs upstream of Lake Powell are operated pursuant to their own criteria, which is not affected by the proposed alternatives.

In addition to the potential impacts that may occur within the main stem Colorado River corridor, the SEIS alternatives may also affect the water supply that is available to specific Colorado River water users in the Lower Basin due to the allocation of reductions in the proposed alternatives. The following water agency service areas are included in the geographic scope of analysis:

- Arizona water users and Tribes, particularly the water users in the Central Arizona Project (CAP) service area
- The SNWA service area
- The MWD service area

The environmental consequences analysis focuses on the period between operating years 2024 and 2026 during which the alternatives considered would be implemented, as described in **Section 2.4**, Implementation. The focus on the 2024 operating year is based on the need to promptly develop additional operational tools in light of historically low reservoir elevations. The alternatives also describe operations for 2025–2026. The SEIS analyzes the alternatives for the 2025–2026 time frame across affected resource areas to the extent that information is available. There is more uncertainty in the 2025–2026 analysis (both from a hydrologic and resource impact standpoint); accordingly, the Department may select an alternative to apply in the 2024 operating year with future analysis, as needed, to be performed before potentially revising the selected alternative for 2025–2026 operations. Although impacts of the proposed alternatives would extend beyond 2026, the analysis does not examine impacts beyond 2026. This is because Reclamation is in the process of preparing a separate EIS to develop the post-2026 operational strategies. This post-2026 EIS will analyze a full range of alternatives along with the associated impacts.

3.3 Methodology

Hydrologic modeling of the Colorado River system was conducted to determine the potential hydrologic effects of the alternatives. The hydrologic modeling provided projections of potential future Colorado River system conditions (such as reservoir elevations, reservoir releases, and river flows) under the No Action Alternative for comparison with conditions under each action alternative. Due to uncertainties associated with future inflows into the system, multiple simulations were performed for each alternative to explore a range of possible future conditions. All statistics calculated are reflective of the hydrologic scenarios and other assumptions used in modeling. They are not intended to suggest actual probabilities of any events occurring. However, it is meaningful to compare statistics across alternatives to differentiate performance.

Hydrologic modeling also provided the basis for analyzing potential effects of each alternative on other environmental resources, such as recreation, biology, energy, etc. The potential effects on specific resource issues are identified and analyzed for each action alternative and compared to the potential effects on that resource issue under the No Action Alternative. These comparisons are typically expressed in terms of the incremental differences in probabilities (or projected circumstances associated with a given probability) between the No Action Alternative and the action alternatives.

This section provides an overview of the hydrologic modeling used and the framework within which the many simulations were undertaken. Further details regarding the model and modeling assumptions are also provided in **Appendix C**, Colorado River Mid-term Modeling System (CRMMS) Model Documentation, and **Appendix D**, Shortage Allocation Model Documentation. For some of the resource analyses, additional modeling using other techniques was needed to analyze the potential effects on particular resource issues. In most of these cases, the output from the hydrologic modeling was used as input to these other models. The methodologies used for the additional modeling are described in each respective resource section of **Chapter 3**. Models may be updated, as appropriate, between this draft SEIS and publication of the final SEIS.

3.3.1 Alternatives Modeled

Two action alternatives and a No Action Alternative are considered in this SEIS.[1] Each alternative includes specific assumptions with regard to the four sections of the 2007 Interim Guidelines that Reclamation is proposing to modify: Section 2.D, Shortage Conditions; Sections 6.C, Mid-Elevation Release Tier, and 6.D, Lower Elevation Balancing Tier; and Section 7.C, Mid-Year Review. Additional details with respect to the modeling assumptions used to represent each alternative are presented in this section; **Appendix C**, CRMMS Model Documentation; and **Appendix D**, Shortage Allocation Model Documentation.

3.3.2 Period of Analysis

As described in **Section 3.2**, this SEIS addresses guidelines that would be in effect for the remainder of the interim period under the 2007 Interim Guidelines from the 2024 through 2026 operating years for Lower Basin shortages and the coordinated operations of Lake Powell and Lake Mead.

3.3.3 Model Description

Future Colorado River system conditions during the analysis period under the No Action Alternative and the action alternatives were simulated using CRMMS. The model framework used for this process is a commercial river modeling software called RiverWare™; a generalized river basin modeling software package developed by the University of Colorado through a cooperative arrangement with Reclamation and the Tennessee Valley Authority. While it uses the same software as Colorado River Simulation System (CRSS), which was the model used for the 2007 FEIS, CRMMS is used to produce mid-term projections of system conditions for outlooks up to five years as opposed to the longer-term outlooks projected using CRSS.

CRMMS simulates the operation of the major reservoirs on the Colorado River and provides information regarding the projected future state of the system on a monthly basis in terms of output variables including the amount of water in storage, reservoir elevations, releases from the dams, the amount of water flowing at various points throughout the system, and the diversions to and return flows from the water users throughout the system. The basis of the simulation is a mass balance (or water budget) calculation that accounts for water entering the system, water leaving the system (e.g., from consumptive use of water, trans-basin diversions, evaporation), and water moving through the system (i.e., either stored in reservoirs or flowing in river reaches). Further explanation of the model is provided in **Appendix C**. The model was used to project the future conditions of the Colorado River system on a monthly time-step for the period September 2022 through December 2026.

The input data for the model includes monthly unregulated inflow forecasts based on the September 2022 forecast, various physical process parameters such as the evaporation rates for each reservoir, initial reservoir conditions as of August 31, 2022, and the future depletion schedules for entities in the Lower Basin and for Mexico. For the first year of the model run, water depletion schedules use water orders that reflect shortage conditions, DCP contributions, Minute 323, and other signed system conservation agreements. For the remaining years in the model run, water depletion schedules reflect "normal" schedules, and represent near-term historical trends in water use. For

[1] In addition, Reclamation analyzed external proposals for alternatives, or components thereof, in **Appendix B**, as further described in **Section 2.1**, Development of the Alternatives.

purposes of this SEIS, depletions are defined as diversions from the river less the return flow credits, where applicable.

The rules of operation of the Colorado River mainstream reservoirs, including Lake Powell and Lake Mead, for each alternative are also provided as input to the model. These sets of operating rules describe how water is released and delivered under various hydrologic conditions. Further explanation of the operating rules for each alternative is provided in **Appendix C**.

The future hydrology used as input to the model consisted of three sets of 30 Ensemble Streamflow Prediction (ESP) traces.[2] The three sets are 80 percent, 90 percent, and 100 percent of the official September 2022 unregulated inflow forecast, allowing Reclamation to explore a wider range of low-flow hydrologic scenarios beyond those experienced during the recent 30 years (1991–2020). See **Appendix C** for additional details on these hydrologic ensembles.

3.3.4 Modeling Assumptions

Assumptions Common to All Alternatives

In addition to the specific operating rules necessary to model each of the alternatives (discussed in **Chapter 2**; **Appendix C**, CRMMS Model Documentation; **Appendix D**, Shortage Allocation Model Documentation; and the following section), the modeling of Colorado River system operations also requires certain assumptions about various aspects of water delivery and system operations that are common to all alternatives.

CRMMS Assumptions for All Alternatives

Detailed assumptions for CRMMS can be found in **Appendix C** and are summarized here. Assumptions with regard to reduction of deliveries to the Lower Division States under each alternative are described in **Sections 2.7 and 2.8**, as well as **Section 3.3.9**, below.

- All simulations were performed with a start date of September 2022 and an end date of December 2026.
- If the pool elevation at Lake Powell drops below 3,490 feet, it is assumed that only three of the four river outlet works would be available for use at any given time because of the need for periodic inspections and any associated maintenance activities. Reclamation believes this is a conservative and prudent estimation given the historical and future operations and maintenance requirements for the river outlet works.
- DCP contributions and intentionally created surplus (ICS) assumptions are consistent with the official September 2022 CRMMS simulation.
- The analysis for each alternative includes modeled water delivery reductions to Mexico under low-elevation reservoir conditions and Mexico's recoverable water savings that contribute to the BWSCP in accordance with Minute 323 to the 1944 Water Treaty. This differs from the assumed 16.67 percent of the total shortage analyzed in the 2007 FEIS.

---

[2] This input is based on an ensemble of unregulated streamflow forecasts developed by the National Weather Service's Colorado Basin River Forecasting Center.

- Hourly, daily, and monthly releases from Lake Powell will be consistent with the LTEMP so long as sufficient water is available for annual releases. Minimum flows analyzed in the LTEMP were 5,000 cfs at night and 8,000 cfs during the day. If these minimum flows are not possible due to the projected monthly release volume, the model could simulate flows lower than the minimum flows analyzed in the LTEMP.
- The DROA releases from Flaming Gorge—projected 500 kaf for May 2022 through April 2023[3]—are included in the tier determination and balancing releases, as are the 2021 DROA releases (which totaled 161 kaf from Flaming Gorge and Aspinall), consistent with the official September 2022 CRMMS simulation.
- For Lower Division State and Mexico use, in the first year of the model run, water depletion schedules use water orders that reflect shortage conditions, DCP contributions, reductions under low-elevation reservoir conditions, BWSCP contributions per Minute 323, and signed system conservation agreements. For the remaining years in the model run, water depletion schedules reflect "normal" schedules, and represent near-term historical trends in water use. The 2007 FEIS consumptive use schedules were based on entitlements. These "baseline/normal" water depletion schedules are then reduced by 2007 Interim Guidelines shortages, DCP reductions, reductions under low-elevation reservoir conditions, BWSCP contributions per Minute 323, and/or additional shortages in the action alternatives.
- It is assumed that annual releases are representative of annual flows within the reach of Davis Dam to Parker Dam, Parker Dam to Cibola Gage, and Cibola Gage to Imperial Dam.
- For the purpose of this SEIS, shortages implemented through operational decisions are referred to as "shortages," whereas shortages incurred as a result of unplanned or unforeseen hydrologic events and when water delivery requirements cannot be met are referred to as system shortages at dead pool, or "system shortages."[4] Combined, shortages and system shortages may be referred to as "total shortages."

Shortage Allocation Model Assumptions for All Alternatives

Detailed assumptions for the Shortage Allocation Models can be found in **Appendix D** and are summarized here.

Modeling Assumptions for the No Action Alternative

Section 2.6 describes the No Action Alternative in detail. An overview of assumptions for the No Action Alternative include:

CRMMS

- The No Action Alternative includes the continued implementation of the 2007 Interim Guidelines, the 2016 ROD for the Glen Canyon Dam LTEMP and Glen Canyon Dam

[3] The projected 500 kaf DROA release was reduced in March 2023 but is not reflected in the modeling assumptions. It may be updated for the Final SEIS.

[4] System shortages are reported as a total for the entire Lower Basin because there are no explicit assumptions made in the CRMMS associated with how these shortages would be distributed in the Lower Basin. This results in users being shorted "hydrologically" (that is, upstream users access water before downstream users); however, it does not reflect potential implementation of such system shortages.

Operating Criteria, Minute 323, and the 2019 DCPs for operations of Glen Canyon and Hoover Dams.

- The No Action Alternative of this SEIS differs from the No Action Alternative in the 2007 FEIS in terms of updated rules to reflect the 2007 Interim Guidelines and DCPs, input hydrology, time horizon, hydrologic demands, and modeling tool (CRMMS).
- Releases from Lake Powell are based on the operational tiers outlined in the 2007 Interim Guidelines (and described in **Section 2.6**).
- Releases from Lake Mead are based on the Lower Basin condition (normal, shortage, or surplus), as outlined in the 2007 Interim Guidelines, and on the required DCP contributions. DCP contributions and ICS assumptions are consistent with the official September 2022 CRMMS simulation.
- Lake Powell and Lake Mead operations are modeled "as if" 480 kaf of water had been delivered to Lake Mead[5].

Shortage Allocation Model

- The No Action Alternative Shortage Allocation Model assumes a maximum analyzed shortage of 1.1 maf.
- Shortages are characterized by two stages, Stage 1 and Stage 2. In Stage 1, shortages are imposed only upon Arizona and Nevada[6] and continue until the deliveries to the post-1968 water rights holders in Arizona (including the CAP) are reduced to zero. In Stage 2, after deliveries to the fourth-priority entitlements within Arizona are expected to be reduced to zero, additional reductions would be applied to Arizona, California, and Nevada according to Stage 2 ratios. However, the maximum shortage volume simulated in the No Action Shortage Allocation Model does not exceed Stage 1 shortage amounts. The model distributes available water first among states based on the 2007 ROD and 2019 DCPs and subsequently among the entitlement holders within each state based on priority.

Modeling Assumptions for Action Alternative 1

Section 2.7 describes Action Alternative 1 in detail. An overview of assumptions for Action Alternative 1 include:

CRMMS

- Only operational changes for Lake Powell and Lake Mead as per Section 2.D, Section 6.C, and Section 6.D of the 2007 Interim Guidelines were considered, otherwise, operations for Lake Powell and Lake Mead are consistent with the No Action Alternative.

---

[5] The reduction of releases from Lake Powell from 7.48 maf to 7.00 maf in operating year 2022 resulted in a reduced release volume of 0.48 maf that normally would have been released from Glen Canyon Dam to Lake Mead as part of the 7.48 maf annual release volume, consistent with routine operations under the 2007 Interim Guidelines. The reduction of releases from Glen Canyon Dam in operating year 2022 (resulting in increased storage in Lake Powell) did not affect the operating determinations for 2023 and it was accounted for "as if" this volume of water had been delivered to Lake Mead.

[6] Note that this is consistent with an Arizona-Nevada Shortage Sharing Agreement dated February 9, 2007, which covers shortage declarations up to 500 kaf during an Interim Period (ending December 31, 2025). In that agreement, shortage declarations exceeding 500 kaf would be consulted upon by the Secretary, triggered by Lake Mead water surface elevations at or below 1,025 feet.

- The Mid-Elevation Release Tier and Lower Elevation Balancing Tier in Lake Powell are replaced with the Lower Elevation Release Tier.
- The new Lower Elevation Release Tier in Lake Powell is operational if the elevation in Lake Powell at the end of the year is below 3,575 feet. Releases will be between 6.0 and 8.23 maf depending on the elevation of Lake Powell and hydrology. Releases may be further reduced to prevent Lake Powell from dropping below 3,500 feet.
- Physical elevations are used for tier determinations and balancing releases for operating years 2024 through 2026 with no assumptions for the repayment of the 480,000-af reduced delivery from Lake Powell in operating year 2022.
- Deliveries to the Lower Division States during Shortage Condition Year 2024 are different from Shortage Condition Years 2025–2026; these are described in **Section 2.7** and **Section 3.3.9**, respectively.
- Shortage reductions in excess of the 2007 ROD and 2019 DCPs are distributed to the Lower Basin based on priority.
- DCP contributions and ICS assumptions are consistent with the official September 2022 CRMMS simulation.

Shortage Allocation Model

- The Action Alternative 1 Shortage Allocation Model assumes a maximum analyzed shortage of 2.083 maf in 2024 and 4.0 maf in 2025 and 2026.
- Shortages are characterized by two stages, Stage 1 and Stage 2. The model distributes available water first among states and subsequently among the entitlement holders within each state based on priority.

Modeling Assumptions for Action Alternative 2

Section 2.8 describes Action Alternative 2 in detail. An overview of assumptions for Action Alternative 2 include:

CRMMS

- Only operational changes for Lake Powell and Lake Mead as per Section 2.D, Section 6.C, and Section 6.D of the 2007 Interim Guidelines were considered; otherwise, operations for Lake Powell and Lake Mead are consistent with the No Action Alternative.
- The Mid-Elevation Release Tier and Lower Elevation Balancing Tier in Lake Powell are replaced with the Lower Elevation Release Tier, operated the same way as in Action Alternative 1.
- This alternative includes modeling assumptions regarding contributions from the Upper Initial Units of releases from zero to 500,000 af per DROA Year (May 1–April 30), which will conform to the DROA and its implementing documents and will be made only to help protect a Lake Powell elevation of 3,500 feet. The analysis refers to these as "potential DROA contributions."
- Physical elevations are used for tier determinations and balancing releases for operating years 2024 through 2026 with no assumptions for the repayment of the 480 kaf reduced delivery from Lake Powell in operating year 2022.

- Deliveries to the Lower Division States during Shortage Condition Year 2024 are different from Shortage Condition Years 2025–2026 and are described in **Section 2.8**.
- Shortage reductions in excess of the 2007 ROD and 2019 DCPs are distributed in the same percentage across all Lower Basin water users at the specified Lake Mead elevations. The distribution of reductions is based on each user's consumptively used water in 2021.
- DCP contributions and ICS assumptions are consistent with the official September 2022 CRMMS simulation.

Shortage Allocation Model

- The Action Alternative 2 Shortage Allocation Model assumes a maximum analyzed shortage of 2.083 maf in 2024 and 4.0 maf in 2025 and 2026.
- The Shortage Allocation Model for Action Alternative 2 distributes shortage reductions in addition to the 2007 ROD and 2019 DCPs distributed in the same percentage across all Lower Basin water users based on 2021 adjusted consumptive use.

3.3.5 Shortage Sharing and Water Delivery Reduction Assumptions

A summary of modeling assumptions with respect to the reduction of deliveries to the Lower Division States, including the distribution of shortages by state for 2024, was provided in **Sections 2.7** and **2.8**.

As described in **Section 3.2**, Reclamation anticipates that there may be additional analysis and outreach before implementing additional changes to the 2007 Interim Guidelines for the 2025 and 2026 operating years. However, for purposes of modeling and analysis of potential environmental consequences from the alternatives in 2025 and 2026 in this SEIS, Reclamation has made assumptions about how additional shortage volumes from Lake Mead considered under Action Alternatives 1 and 2 would be distributed among Lower Division States and individual users (see **Table 3-1** and **Table 3-2** and **Appendix C** and **Appendix D**). The assumptions are based on the methodologies for distributing additional shortages by priority, for Action Alternative 1, or in the same percentage, for Action Alternative 2, as described in **Sections 2.7** and **2.8**. These assumed shortage volumes are subject to further revision based on any subsequent analyses and outreach after completion of this SEIS.

Table 3-1
Lower Division States' Shortages and Contributions by State, Action Alternative 1 (2025–2026)
(All volumes in 1,000 af)

Lake Mead Elevation (feet)	2007 ROD Shortage + 2019 DCP Contributions				2025–2026 Action Alternative 1 Additional Shortage*				2025–2026 Total Shortages and Contributions			
	AZ	NV	CA	Total	AZ	NV	CA	Total	AZ	NV	CA	Total
1,090 – >1,075	192	8	0	200	192	8	0	200	384	16	0	400
1,075 – 1,050	512	21	0	533	511	22	0	533	1,023	43	0	1,066
<1,050 – >1,045	592	25	0	617	593	24	0	617	1,185	49	0	1,234
1,045 – >1,040	640	27	200	867	1,025	42	0**	1,067	1,665	69	200	1,734***
1,040 – >1,035	640	27	250	917	1,098	56	12	1,166	1,738	83	262	2,083
1,035 – >1,030	640	27	300	967	1131	63	89	1131	1771	90	389	2250
1,030 – 1,025	640	27	350	1,017	1,180	73	230	1,180	1,820	100	580	2,500
<1,025 – 1,000	720	30	350	1,100	1,198	90	612	1,900	1,918	120	962	3,000
<1,000 - 975	720	30	350	1,100	1,263	103	867	2,233	1,983	133	1,217	3,333
<975 - 950	720	30	350	1,100	1,329	117	1,122	2,567	2,049	147	1,472	3,667
<950	720	30	350	1,100	1,394	130	1,376	2,900	2,114	160	1,726	4,000

*The additional shortage volumes decrease at elevation 1,025 feet because the shortages under the 2007 ROD increase by the same amount. Therefore, the additional shortage amounts necessary to get to the 2.083 maf total are lower.
**The first increment of shortage volumes required by Action Alternative 1 is satisfied by 2019 DCP contributions. In this elevation tier, the 2019 DCP contributions for California exceed the 2024 shortage volume under Action Alternative 1, which follows the priority system.
***The state distributions in the 2025–2026 Total Shortage columns reflect Action Alternative 1 shortages plus remaining contributions to satisfy the 2019 DCPs. In this elevation tier, the California DCP contribution when added to the total shortage exceeds the total volume of Action Alternative 1.

Table 3-2
Lower Division States' Shortages and Contributions by State, Action Alternative 2 (2025–2026)
(All volumes in 1,000 af)

Lake Mead Elevation (feet)	2007 ROD Shortage + 2019 DCP Contributions				2025–2026 Action Alternative 2 Additional Shortage					2025–2026 Total Shortages and Contributions			
	AZ	NV	CA	Total	Percentage Additional Reduction*	AZ	NV	CA	Total	AZ	NV	CA	Total
1,090 – >1,075	192	8	0	200	2.67%	75	8	117	200	267	16	117	400
1,075 – 1,050	512	21	0	533	7.11%	199	21	313	533	711	42	313	1,066
<1,050 – >1,045	592	25	0	617	8.23%	230	25	362	617	822	50	362	1,234
1,045 – >1,040	640	27	200	867	11.56%	324	35	509	867	964	62	709	1,734
1,040 – >1,035	640	27	250	917	15.55%	435	47	684	1,166	1,075	74	934	2,083
1,035 – >1,030	640	27	300	967	17.11%	479	51	753	1,283	1,119	78	1,053	2,250
1,030 – 1,025	640	27	350	1,017	19.77%	554	59	870	1,483	1,194	86	1,220	2,500
<1,025 – 1,000	720	30	350	1,100	25.33%	709	76	1,115	1,900	1,429	106	1,465	3,000
<1,000 - 975	720	30	350	1,100	29.77%	834	89	1,310	2,233	1,554	119	1,660	3,333
<975 - 950	720	30	350	1,100	34.23%	958	103	1,506	2,567	1,678	133	1,856	3,667
<950	720	30	350	1,100	38.67%	1,083	116	1,701	2,900	1,803	146	2,051	4,000

*Percentage of 2021 consumptive use.

3.4 Resource Issues Not Analyzed in Detail

As described in **Section 1.5.2** and **Table 1-1**, some resource issues are not considered potentially significant, given current conditions and the actions considered in the alternatives; therefore, they are not analyzed in this SEIS. **Table 1-1** summarizes the rationale for eliminating resource issues from detailed analysis. Resource issues considered but not analyzed in detail in this SEIS include:

- Geology and soils
- Minerals
- Noise
- Transportation and traffic

3.5 Cumulative Impacts

The CEQ's regulations (40 CFR 1500 through 1508) implementing the procedural provisions of NEPA defines cumulative impacts as the following:

> "…the impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (Federal or non-Federal) or person undertakes such other actions. Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time (40 CFR 1508.7)."

Cumulative impacts refer to two or more individual impacts that, when considered together, are significant or that compound or increase other environmental impacts. Cumulative impacts can be categorized as additive and interactive. An additive impact results from additions from one kind of source either through time or space. An interactive impact results from more than one kind of source.

This section addresses the cumulative impacts of the proposed alternatives combined with other regional water supply or closely related projects in the region. Closely related projects that could result in significant cumulative impacts are briefly described below. In addition, Reclamation considered other projects, such as the Lake Powell Pipeline Project and future state conservation projects, but did not bring them forward for cumulative impacts analysis. This is because the projects were too speculative at this time to be considered reasonably foreseeable, did not closely relate to basin operations and regional water supply, or would not result in significant cumulative impacts. Additional projects will be considered for analysis of cumulative impacts as part of the post-2026 EIS, as appropriate.

3.5.1 Glen Canyon Dam/Smallmouth Bass Flow Options

Reclamation's Upper Colorado Basin Region is preparing an environmental assessment (EA) regarding experimental operations at the Glen Canyon Dam to prevent smallmouth bass from establishing. The decline of water levels in Lake Powell to historically low levels has contributed to record high water temperature releases through the Glen Canyon Dam. Below the dam, these warm water releases are creating ideal spawning conditions for smallmouth bass, a predatory invasive fish species. If smallmouth bass successfully spawn and establish below Glen Canyon Dam and then expand downstream into the Grand Canyon, they will likely become a threat to the federally protected humpback chub and other native fish. The purpose of Reclamation's proposed action is to prevent the establishment of smallmouth bass below the Glen Canyon Dam using dam operations to reduce water release temperatures.

Reclamation is considering two alternatives, one of which includes four experimental flow options that are designed to reduce the temperature of the water released through the dam to prevent smallmouth bass from establishing below the dam. All four options would include releases of water through the river outlet works, which are lower. This means the water release temperature would be colder; however, power is only generated when water is released through the penstocks, which would result in impacts on hydropower generation. The flow options would not result in any changes to monthly or yearly release volumes but would instead change how and when those releases took place.

3.6 Hydrologic Resources

3.6.1 Affected Environment

The 2007 FEIS described how hydrologic resources within the study area, which begins with Lake Powell and extends downstream along the Colorado River to the SIB with Mexico, would be potentially affected by the implementation of the alternatives. These same hydrologic resources have the potential to be affected by the proposed alternatives evaluated in this SEIS; these resources include:

- Reservoir storage, reservoir releases, and corresponding changes in Colorado River flows downstream of the reservoirs
- Groundwater within the Colorado River corridor and/or offstream

To analyze potential effects on these resources, the 2007 FEIS presented an overview of the hydrology of the Basin and hydrologic resources by river reach (see **Map 3-1**). The overall characteristics and connectivity of the basin and reaches remain unchanged from information presented in the 2007 FEIS. However, three factors in the US have affected hydrologic resources in the Basin since issuance of the 2007 FEIS:

1) Interim Guidelines were established in December 2007 from the FEIS Preferred Alternative and several operational refinements according to the ROD for the Colorado River Interim Guidelines for Lower Basin shortages and coordinated operations for Lake Powell and Lake Mead. These 2007 Interim Guidelines were implemented to "address shortage determinations and coordinated reservoir operations" under drought and low reservoir conditions (Reclamation 2007). As listed in the ROD, the 2007 Interim Guidelines remain in effect for supply and reservoir operating decisions through 2026.

2) In May of 2019, the DCPs were signed to address ongoing historic drought in the Basin. In May 2019, components of the Lower Basin DCP were implemented and the Lower Basin DCP was fully implemented during the 2020 operating year. Starting in July 2021, the 2021 Upper Basin DROA, which is part of the Upper Basin DCP, was implemented. Implementation of the 2022 Upper Basin DROA began in May 2022. Management of releases and reservoir water levels continues to be conducted in accordance with these DCPs.
3) As described in **Chapter 1**, a key driver for this SEIS is the worsening drought and low-runoff conditions in the Basin, which have continued to alter reservoir storage, releases, and flows.

The 2007 FEIS used historical hydrologic conditions within the Basin from 1906 through 2005 to inform how changes in operations could impact hydrologic conditions for the interim period between 2007 and 2026. This SEIS incorporates updated hydrologic information through 2022 to better describe evolving characteristics of hydrologic resources within the affected environment. The updated information for these resources, by river reach, captures the implementation of the 2007 Interim Guidelines, 2019 DCPs, Minute 323, and drought conditions within the Basin. The updated hydrologic conditions within the Basin were used to inform modeling assumptions within the SEIS.

Hydrologic Overview

The 2007 FEIS presented the hydrology of the Basin, including the various hydrologic resources and river reaches the Basin contains. This section provides updated descriptions of hydrologic resources within the Basin through 2022 to capture the worsening drought conditions. It also provides an update to releases and reservoir levels as a result of implementing the 2007 Interim Guidelines and the Upper Basin DCP and Lower Basin DCP. The Colorado River Basin Climate and Hydrology: State of the Science (State of the Science) (Lukas, J. and Payton, E. 2020) report provided a comprehensive assessment of Basin hydroclimate conditions and trends through 2019. Key findings from the report are summarized below, updated through 2022, where appropriate.

Since 2000, the Basin has experienced persistent drought conditions, exacerbated by a warming climate, leading to a 20 percent decrease in average annual Upper Basin (at Lee Ferry) natural flows (Reclamation 2022c). This period, from 2000 to 2023, is the driest 23-year period in more than a century. These conditions amount to a cumulative streamflow deficit of about 70 maf relative to twentieth-century conditions (Reclamation 2022c). Approximately 92 percent of the natural Basin streamflow originates from the Upper Basin, with snowmelt being the primary source of runoff. Historically, the primary driver for the hydrologic drought in the Basin has been below-normal precipitation over the winter, resulting in reduced snowmelt in the spring, but warming temperatures are playing an increasing role as evaporative losses and soil moisture deficits increase.

BUREAU OF RECLAMATION

Map 3-1
Delineated Colorado River Reaches for the SEIS Analysis

Colorado River reach:

- 1 Gypsum Canyon to Glen Canyon Dam
- 2 Glen Canyon Dam to Separation Canyon
- 3 Separation Canyon to Hoover Dam
- 4 Hoover Dam to Davis Dam
- 5 Davis Dam to Parker Dam
- 6 Parker Dam to Cibola Gage
- 7 Cibola Gage to Imperial Dam
- 8 Imperial Dam to Northerly International Boundary (NIB)
- 9 NIB to Southerly International Boundary (SIB)

- Dam or the end of a reach
- Colorado River above and below the geographic scope of analysis
- Colorado River tributary
- Colorado River Basin, Upper and Lower Basins
- States in the Colorado River Basin

While portions of northwestern Mexico are part of the Basin, these areas are not within the geographic scope of analysis for this SEIS. This is because the SEIS is not considering alternative actions that would change water deliveries to Mexico. The provisions of the 1944 Water Treaty and implementing Minutes are not affected by this SEIS.

This page intentionally left blank.

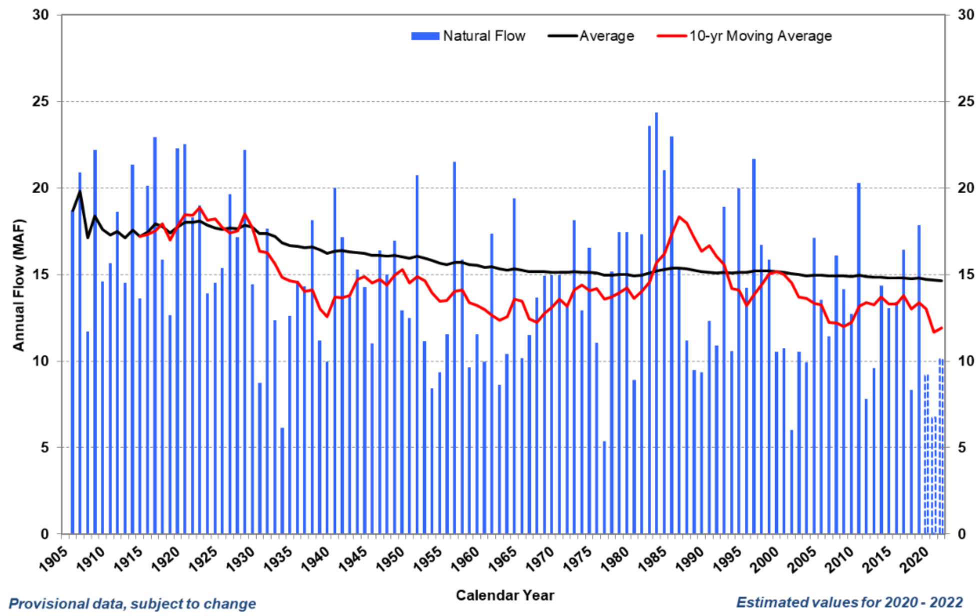
In addition, annual water use in the Basin has exceeded the annual inflows in most years since 2000. This resulted in a depletion of storage down to 26 percent of the total combined capacity of Lake Powell and Lake Mead by the end of operating year 2022 (Reclamation 2023d). Since issuance of the 2007 FEIS, the hydroclimate changes in the Basin include further increases in temperature, continued below-normal precipitation, declining snowpack water volume and annual streamflow, and earlier snowmelt runoff. Since 2000, the average temperature across the Basin has been two degrees Fahrenheit warmer than the twentieth-century average; the warmest 10-year period on record occurred from 2012 to 2021 (National Oceanic and Atmospheric Administration 2023).

To describe precipitation in the Basin, the State of the Science report focused on multi-decadal trends due to the Basin's high interannual variability and the effects of short-term trends associated with the El Niño-Southern Oscillation. For both the Upper Basin and Lower Basin, a declining (but statistically non-significant) precipitation trend was noted over the period from 1980 to 2019. During the 1980 to 2019 period, precipitation over the cold season (October through March), which typically falls as snow, showed a greater declining trend than precipitation over the warm-season months. Higher elevations in the Upper Basin are more resilient to reduced snowpack than the lower elevations; however, studies summarized in the State of the Science report indicate that snowmelt runoff is occurring 1–3 weeks earlier than the average timing prior to 2000.

During the historical period analyzed in the FEIS (1906–2007), the average annual natural flow at the Lees Ferry Gaging Station was calculated to be 14.916 maf. Annual natural flows during this timeframe ranged from 5.378 maf to 24.356 maf. According to the 2007 FEIS, natural flows at Lees Ferry were calculated based on observed (gage) flow, and they were corrected for upstream reservoir changes in storage and release, losses including evaporation, and depletions due to agriculture and domestic uses. Since the implementation of the 2007 Interim Guidelines (2008 to 2022), the annual natural flow at the Lees Ferry Gaging Station have ranged from 6.733 maf (2021) to 20.303 maf (2011) and averaged 12.674 maf. **Figure 3-1** shows the natural flows calculated at the Lees Ferry Gaging Station for 1922 through 2022.

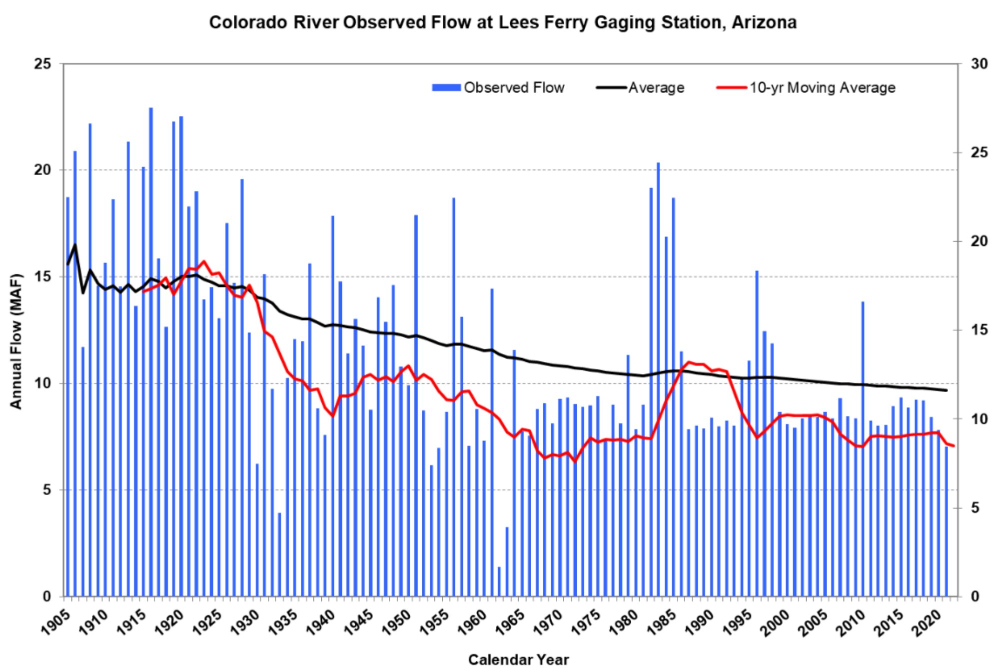
Beginning in 2008, annual observed flows (which do not account for the above-mentioned factors) at the Lees Ferry Gaging Station have decreased. The annual observed flow at Lees Ferry during the historical period since the Glen Canyon Dam was built (1963-2007) ranged from 1.383 maf (when the dam was built in 1963) to 20.374 maf (1984) with an average of 9.691 maf. Since the implementation of the 2007 Interim Guidelines (2008 to 2022), the annual observed flows at the Lees Ferry Gaging Station have ranged from 7.041 maf to 13.846 maf and averaged 8.877 maf. This average annual observed flow is approximately 0.814 maf less than the average observed flow presented in the 2007 FEIS. According to the 2020 State of the Science report, a 2-year average flow of less than 15 maf at Lees Ferry is considered a streamflow deficit. The maximum annual observed flow of 13.846 maf occurred in 2011, and it was approximately 6.528 maf less than the maximum flow that occurred during the 1963–2007 dataset (in 1984). **Figure 3-2** shows the observed flows recorded at the Lees Ferry Gaging Station for 1922 through 2022.

Figure 3-1
Colorado River Natural Flow at Lees Ferry Gaging Station, Arizona



Source: Reclamation 2023e

Figure 3-2
Colorado River Observed Flow at Lees Ferry Gaging Station, Arizona



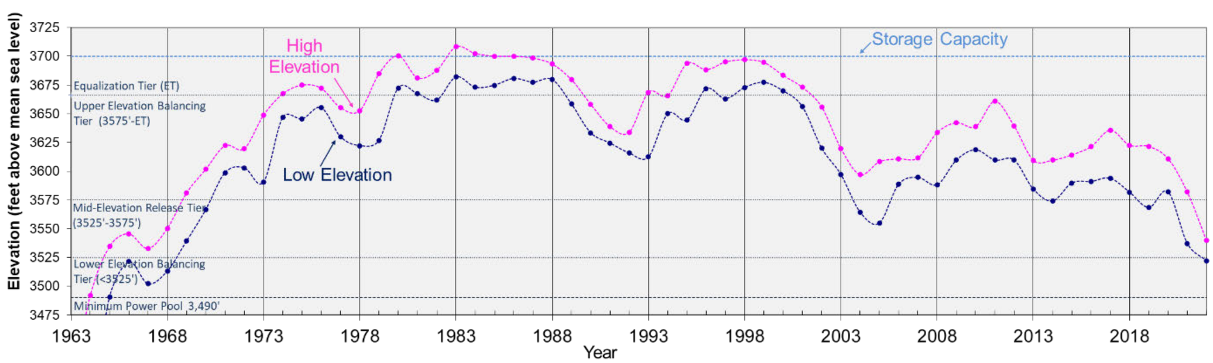
Source: Reclamation 2023e

Lake Powell and Glen Canyon Dam

As presented in the 2007 FEIS, the operating range of Lake Powell is between a water surface elevation of 3,490 feet (corresponding to the minimum power pool) and 3,700 feet (corresponding to the top of the Glen Canyon Dam spillway). Since implementation of the 2007 Interim Guidelines (2008 to 2022), water surface elevations at Lake Powell have been variable, but a steep decline began in 2018. Water surface elevation data were analyzed for the years 2008 through 2022 from Reclamation's Upper Basin Hydrologic dataset. The operating range during this period was between 3,522.2 feet (occurring in 2022) and 3,660.9 feet (occurring in 2011). The average operating elevation was 3,602.3 feet, which is well below the average elevation throughout the 1980s and late 1990s.

Since 2017, the annual average water surface elevation at Lake Powel has declined approximately 87 feet. Lake Powell's annual high-water elevation and annual low-water elevation for 1963 through 2022 are shown in **Figure 3-3**. (Note that these data include changes to elevations associated with operation of Lake Powell in accordance with the 2007 Interim Guidelines, the Upper Basin DCP (activated starting in 2020), and the ROD for the Glen Canyon Dam LTEMP.[7] Minimum flows through the Glen Canyon Dam that were analyzed in the LTEMP were 5,000 cfs at night and 8,000 cfs during the day. Possible effects of the proposed action alternatives on future elevations at Lake Powell are discussed in **Section 3.6.2** below.

Figure 3-3
Lake Powell Annual High and Low Elevations (1963–2022)



Source: Reclamation 2023e

The 2007 FEIS did not consider effects to groundwater elevations in the vicinity of Lake Powell. Fluctuations of reservoir levels may impact adjacent groundwater levels. Declining reservoir elevations since the 2007 FEIS may be mirrored in declining groundwater elevations.

Glen Canyon Dam to Lake Mead

As described in the 2007 FEIS, flows in the river reach between Glen Canyon Dam and Lake Mead are primarily controlled by Glen Canyon Dam releases from Lake Powell. Additional contributions to this reach of the Colorado River are received from tributaries, including the Paria River and Little Colorado River. Since the implementation of the 2007 Interim Guidelines (2008 to 2022), annual

[7] ROD for the Glen Canyon Dam LTEMP FEIS, December 2016. Internet website: https://ltempeis.anl.gov/documents/docs/LTEMP_ROD.pdf.

inflow from the Little Colorado River ranged from 204,300 to 392,900 af, averaging 274,600 af. During the same period, the annual inflow from the Paria River ranged from 8,100 to 27,600 af, averaging 17,600 af. In comparison, during this period, the flows in the Colorado River just below the confluence of the Little Colorado River (USGS gage 09402500) ranged from 7.556 maf to 14.239 maf, averaging 9.311 maf (USGS 2023c). From 2008 to 2022, the inflows from the Paria River and Little Colorado River represented approximately 3.1 percent of the average streamflow within this reach of the Colorado River. This is similar to the total contribution of streamflow from the Paria and Little Colorado Rivers to this reach presented in the 2007 FEIS, which was less than 3 percent.

The 2007 Interim Guidelines have governed annual releases from Glen Canyon Dam since they were implemented in 2008. Under the 2007 Interim Guidelines, the minimum and maximum releases from Glen Canyon Dam are determined by the assigned operating tier for Lake Powell (Equalization Tier, Upper Elevation Balancing Tier, Mid-Elevation Release Tier, or Lower Elevation Balancing Tier). Since 2008 (through 2022), the Upper Elevation Balancing Tier has been the most common operation type, allowing releases between 7.0 and 9.0 maf (see **Table 3-3**). Glen Canyon Dam releases for this period have ranged from 7.04 to 13.85 maf and averaged 8.81 maf. The average annual releases presented in the 2007 FEIS from 1996 to 2007 were 9.98 maf. This 1.16-maf decrease in average annual releases can be attributed to hydrologic conditions in the Basin and the implementation of the 2007 Interim Guidelines. Changes to releases from Glen Canyon Dam as a result of the proposed action alternatives are further discussed in **Section 3.6.2**, Environmental Consequences below.

Table 3-3
Summary of Lake Powell and Lake Mead Coordinated Operations 2008–2022

Year	Lake Powell Operations					Lake Mead Operations
	Operating Tier	April Adjustment	Operating Year Unregulated Inflow (Percent Average)[7]	Release Volume (maf)	Equalization Volume (maf)	Operating Condition
2008	Upper Elevation Balancing	Equalization	126	8.98	0.75	Normal/ICS Surplus
2009	Upper Elevation Balancing	None	106	8.24 [1]	—	Normal/ICS Surplus
2010	Upper Elevation Balancing	None	88	8.23	—	Normal/ICS Surplus
2011	Upper Elevation Balancing	Equalization	166	12.52	4.29 [2]	Normal/ICS Surplus
2012	Equalization	N/A	51	9.47	1.23 [3]	Normal/ICS Surplus
2013	Upper Elevation Balancing	None	53	8.23	—	Normal/ICS Surplus
2014	Mid-Elevation Release	N/A	108	7.48	—	Normal/ICS Surplus

Year	Lake Powell Operations					Lake Mead Operations
	Operating Tier	April Adjustment	Operating Year Unregulated Inflow (Percent Average)[7]	Release Volume (maf)	Equalization Volume (maf)	Operating Condition
2015	Upper Elevation Balancing	Balancing	106	9.00	—	Normal/ICS Surplus
2016	Upper Elevation Balancing	Balancing	100	9.00	—	Normal/ICS Surplus
2017	Upper Elevation Balancing	Balancing	124	9.00	—	Normal/ICS Surplus
2018	Upper Elevation Balancing	Balancing	48	9.00	—	Normal/ICS Surplus
2019	Upper Elevation Balancing	Balancing	135	9.00	—	Normal/ICS Surplus
2020[4]	Upper Elevation Balancing	None	61	8.23	—	Normal/ICS Surplus DCP Contributions
2021[5]	Upper Elevation Balancing	None	36	8.23	—	Normal/ICS Surplus DCP Contributions
2022	Mid-Elevation Release Tier	Adjusted in May 2022[6]	63	7.00	—	Level 1 Shortage DCP Contributions

Source: Adapted from Reclamation 2020a

[1] In 2009, while the scheduled release volume was 8.23 maf, the actual release was 8.24 maf due to rounding and a release of 5,702 acre-feet above 8.23. Balancing did not occur in 2009.

[2] The total 2011 equalization volume was 5.52 maf, with 4.29 maf released in operating year 2011. The remaining equalization volume was released as soon as practicable and was released fully by December 31, 2011.

[3] Although Lake Powell operated in the Equalization Tier in 2011, 8.23 maf was released in operating year 2012 due to dry conditions. The additional release of 1.23 maf was operating year 2011 equalization water released during operating year 2012. The difference between 9.47 maf and 8.23 maf is due to rounding.

[4] Supplemental data for 2020 provided by AOP (Reclamation 2020b).

[5] Supplemental data for 2021 provided by AOP (Reclamation 2021c).

[6] Lake Powell's release was reduced by 480,000 af during Water Year 2022 in May 2022: 2022 Glen Canyon Dam Operations Decision Letter (usbr.gov).

[7] The unregulated inflow statistics (percent average) are based on a mean of the 30-year period 1991-2020 for all years.

As stated in the 2007 FEIS, this reach is within the Grand Canyon, which limits the hydraulic connection to groundwater. The Stream Flow and Losses of the Colorado River in the Southern Colorado Plateau White Paper 5 (White Paper 5) (Wang, J. and Schmidt, J. 2020) states that approximately 150,000 af per year is lost as seepage around the Glen Canyon Dam. The incised nature of this river corridor has remained relatively unchanged since issuance of the 2007 FEIS. Based on the analyses performed in the 2007 FEIS, the 2007 Interim Guidelines were not anticipated to have affected groundwater levels in this reach. Therefore, it is assumed that groundwater levels have remained the same since 2007 for this reach.

The 2007 FEIS did not consider effects on groundwater elevations in the vicinity of Lake Mead. Fluctuations of reservoir levels may impact adjacent groundwater levels. Declining reservoir elevations since the 2007 FEIS may be mirrored in declining groundwater elevations.

Lake Mead and Hoover Dam

The operating range of Lake Mead is between a water surface elevation of 895 feet and 1,219.6 feet. The top of the Hoover Dam spillway is at elevation 1,221 feet, which allows for 1.5 maf of flood control storage above the maximum operating elevation (1,219.6 feet). Improvements to the Hoover Dam since the 2007 FEIS include the installation of five new wide-head turbines in 2018 to improve operations at lower water levels. The new turbines updated the minimum power pool elevation to 950 feet. Water surface elevations above 895 feet can still allow releases through the intake towers.

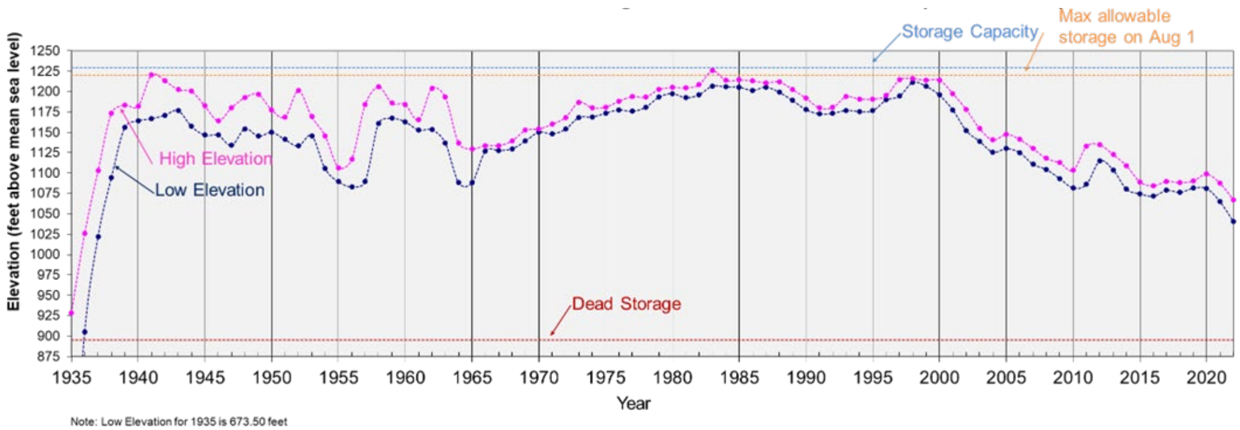
Since the construction of the Hoover Dam in 1935, it took Lake Mead approximately 4 years to fill up to an average annual water surface elevation of 1,172 feet. The water surface elevation of Lake Mead was highly variable from 1939 until the Glen Canyon Dam at Lake Powell came online in 1963, fluctuating from 1,098 feet to 1,195 feet. With the operation of the upstream Glen Canyon Dam, the elevations in Lake Mead began to increase steadily to an average annual peak of 1,215 feet in 1983. Elevations declined slightly through the late 1980s and early 1990s until peaking again in 1998 at an average annual elevation of 1,214 feet. After 1998, elevations began to decline sharply to a new low of 1,118 feet in 2007 when the 2007 Interim Guidelines were implemented. According to the 2007 FEIS, the average annual water surface elevation of Lake Mead during the historical period from 1939 (when Lake Mead filled) through 2007 was 1,170 feet.

Since implementation of the 2007 Interim Guidelines (2008 to 2022), water surface elevations at Lake Mead have steadily declined. Water surface elevation data were analyzed for the years 2008 through 2022 from Reclamation's hydrologic database. The annual operating range during this period was between 1,040.6 feet (occurring in 2022) and 1,134.5 feet (occurring in 2011). The average annual operating elevation was 1,090.2 feet, which is approximately 71 feet below the average annual water surface elevation from 1939 to 2007. Since 2011, the annual average water surface elevation at Lake Mead has declined approximately 94 feet. **Figure 3-4** shows the annual high-water elevation and annual low-water elevation of Lake Mead for 1935 through 2022.

As with the data presented above for Lake Powell, the information presented on Lake Mead includes changes to elevations associated with operation of Lake Mead in accordance with the 2007 Interim Guidelines, Minute 323, and the 2019 Lower Basin DCP. Possible effects of the proposed action alternatives on future elevations at Lake Mead are discussed in **Section 3.6.2**, below.

As discussed in the 2007 FEIS, Hoover Dam releases are managed on an hourly basis to maximize the value of generated power by providing peaks during high-demand periods. A discussion regarding electrical power generation is included in **Section 3.15**.

Figure 3-4
Lake Mead Annual High and Low Elevations (1935–2022)



Source: Reclamation 2023f

Since the issuance of the 2007 FEIS, Lake Mead operated in a normal/ICS condition each year 2008 through 2021 and in a Level 1 shortage condition in 2022 (see **Table 3-3**). In addition, contributions under the Lower Basin DCP were required in the years from 2020 through 2022. From 2008 through 2022, the elevation of Lake Mead on January 1 has ranged from 1,066.4 feet to 1,114.8 feet.

As reported in the 2007 FEIS, annual Hoover Dam releases from Lake Mead ranged from 8.275 to 12.781 maf and averaged 10.199 maf for the period from 1996 through 2007. With the 2007 Interim Guidelines in place since issuance of the 2007 FEIS, annual Hoover Dam releases since 2008 (through 2022) have ranged from 8.515 to 9.615 maf and averaged 9.185 maf. This is a decrease of 1.014 maf in average annual releases. Decreases in releases are due to the ICS activity and surplus guideline operations since the issuance of the 2007 Interim Guidelines and the 2000 Interim Surplus Guidelines.

Hoover Dam to Davis Dam

As described in the 2007 FEIS, flows within the 67-mile reach from Hoover Dam (Lake Mead) to Davis Dam (Lake Mohave) are almost entirely comprised of releases from Hoover Dam, with less than 1 percent contributed from tributary inflows.

Implementation of the 2007 Interim Guidelines has reduced the average annual releases from Hoover Dam by approximately 1.01 maf (annually averaging 9.185 maf). The 2007 FEIS modeling results for the alternatives for 2008 through 2026 modeled a 46.7 percent probability of occurrence for Hoover Dam annual releases between 8.01 and 9 maf, 40.5 percent for releases between 9.01 and 10 maf, and 12.6 percent for releases greater than 10 maf. In comparison, the actual annual Hoover Dam releases since 2008 (through 2022) that were between 8.01 and 9 maf occurred approximately 27 percent of the time, add releases between 9.01 and 10 maf occurred the remaining 73 percent of the time. No releases greater than 10 maf have occurred since the 2007 Interim Guidelines were implemented. The actual observed flows for the 2008 to 2022 time period were different than the modeled probabilities for the 2007 FEIS federal alternative.

Similar to the federal action evaluated in the 2007 FEIS, the proposed alternatives being evaluated in the SEIS will not change how Hoover Dam is operated on an hourly and daily basis as long as sufficient water is available.

The implementation of the 2007 Interim Guidelines did not affect the target water surface elevation range of Lake Mohave at Davis Dam. Reclamation has continued to operate Lake Mohave under the same rule curve that determines end-of-month target elevations that were used prior to implementation of the 2007 Interim Guidelines. The water surface elevation continued to range from approximately 630 feet up to 645.7 feet with lower elevations in the fall to provide flood control capacity and higher elevations in the spring. From 1996 to 2007, the average annual water surface elevation was 640.8 feet. Since 2008 (through 2022), the average annual water surface elevation remained the same, at approximately 640.9 feet. The average storage in Lake Mohave has remained approximately 1.6 maf for the last several decades.

As stated in the 2007 FEIS, the upper portion of this reach is within a bedrock canyon that has limited connection to groundwater. Based on the analyses performed in the 2007 FEIS, the 2007 Interim Guidelines were not anticipated to have affected groundwater levels in this reach. Therefore, Reclamation assumed that groundwater levels have remained the same in this reach since 2007. The lower portion of the reach is dominated by Lake Mohave. The 2007 FEIS did not consider effects to groundwater elevations in the vicinity of Lake Mohave; however, fluctuations of reservoir levels may impact adjacent groundwater levels.

Davis Dam to Parker Dam

As described in the 2007 FEIS, flows within the 84-mile reach from Davis Dam (Lake Mohave) to Parker Dam (Lake Havasu) are primarily comprised of releases from Davis Dam, with inflows from the Bill Williams River entering directly into Lake Havasu. The releases from Davis Dam are made to regulate downstream water demands. These releases are scheduled on an hourly basis and coordinated to meet daily release targets and to help meet power demands.

The implementation of the 2007 Interim Guidelines did not explicitly target the release operations of Davis Dam. However, the annual release rates have decreased since implementing the guidelines and further decreases in flow rates would occur with increasing shortage levels. The current Davis Dam minimum daily release is 1,600 cfs and the minimum hourly release is 1,300 cfs (with monitoring). The minimum release for a 30-day month is currently 95,000 af. As reported in the 2007 FEIS, annual Davis Dam releases from Lake Mohave ranged from 8.0 to 12.6 maf and averaged 9.9 maf from 1996 through 2007. Annual Davis Dam releases since 2008 (through 2022) have ranged from 8.2 to 9.3 maf and averaged 8.8 maf. This is a decrease of 1.1 maf in average annual releases.

Inflows from the Bill Williams River depend on the releases from Alamo Dam by the USACE; the 2007 Interim Guidelines did not affect these operations. As stated in the 2007 FEIS, the annual inflow from the Bill Williams River ranged from 1,300 to 702,000 af and averaged 102,000 af for 1906 through 2007. Annual Alamo Dam releases since 2008 (through 2022) have ranged from 15.4 to 501,900 af and averaged 105,000 af. Contributions to Lake Havasu from the Bill Williams River have remained unchanged since the 2007 Interim Guidelines.

Reclamation has continued to operate Lake Havasu under the same rule curve that determines end-of-month target elevations as prior to the 2007 Interim Guidelines. The water surface elevation continued to range from approximately 445 feet up to 450 feet with lower elevations in the fall to provide flood control capacity and higher elevations in the spring. From 1996 to 2007, the average annual water surface elevation was 447.5 feet. Since 2008 (through 2022), the average annual water surface elevation has remained the same, at approximately 447.7 feet. Average storage in Lake Havasu has remained approximately 0.57 maf for the last several decades.

As stated in the 2007 FEIS, the upper portion of this reach is in the Mohave Valley groundwater basin, which is mostly alluvial fill. The 2007 FEIS used a combination of hydrologic and hydraulic models to relate the decreased flow rates to decreased river stage depths, which were used as an indicator for groundwater effects. The 2007 FEIS determined the 2007 Interim Guidelines would result in decreased groundwater elevations of approximately 0.25 to 0.50 feet. Therefore, it is assumed that groundwater levels in this reach have decreased by approximately that much since 2007.

The lower portion of the reach is the Chemehuevi Valley groundwater basin, which is dominated by Lake Havasu. Based on the analyses performed in the 2007 FEIS, the 2007 Interim Guidelines were not anticipated to have affected groundwater levels in this reach. Therefore, Reclamation assumes that groundwater levels have remained the same since 2007.

Parker Dam to Cibola Gage

As described in the 2007 FEIS, flows within the 105-mile reach from Parker Dam (Lake Havasu) to the Cibola Gage primarily consist of releases from Parker Dam. As the last major storage facility on the Colorado River, the releases from Parker Dam are made to regulate downstream water demands.

The implementation of the 2007 Interim Guidelines did not explicitly target the release operations of Parker Dam; these releases are scheduled on an hourly basis and coordinated to meet daily release targets and to help meet power demands. However, the annual release rates have decreased since implementation of the 2007 Interim Guidelines. The current Parker Dam minimum daily release is 1,600 cfs and the minimum hourly release is 1,400 cfs. The minimum release for a 30-day month is currently 95,000 af. As reported in the 2007 FEIS, annual Parker Dam releases from Lake Havasu ranged from 6.19 to 10.3 maf and averaged 7.4 maf from 1996 through 2007. Annual Parker Dam releases since 2008 (through 2022) have ranged from 6.2 to 6.7 maf and averaged 6.4 maf. This is a decrease of 1.0 maf in average annual releases.

The operations of the Headgate Rock Dam and Palo Verde Diversion Dam have remained unchanged since issuance of the 2007 FEIS. These diversion dams are operated by the BIA and the Palo Verde Irrigation District, respectively.

As stated in the 2007 FEIS, the reach from Parker Dam to the Imperial Dam is in one large groundwater basin (referred to as the Parker Valley, Cibola Valley, and Palo Verde Valley) that is mostly alluvial fill. The 2007 FEIS used a combination of hydrologic and hydraulic models to relate the decreased flow rates to decreased river stage depths, which were used as an indicator for groundwater effects. The 2007 FEIS determined the 2007 Interim Guidelines would result in decreased groundwater elevations of approximately 0.15 to 0.30 feet. Therefore, Reclamation assumes that groundwater levels in this reach have decreased by approximately that much since 2007.

Cibola Gage to Imperial Dam

As described in the 2007 FEIS, flows within the 38-mile reach from the Cibola Gage to Imperial Dam are primarily comprised of releases from Parker Dam minus the diversions at Headgate Rock Dam and Palo Verde Dam. The flows in this reach are typically comprised of US' water deliveries for diversions downstream of Palo Verde, including diversions at Imperial Dam, and deliveries to Mexico as required by the 1944 Water Treaty and Minute 323.

As described above, implementation of the 2007 Interim Guidelines did not change operations of Parker Dam, but annual releases have decreased since their implementation in 2008 due to decreased upstream releases from Lake Powell and Lake Mead and thus decreased inflows into Lake Havasu. Average flow rates for the Colorado River at the Cibola Gage ranged from 1,488 to 18,168 cfs and averaged 8,931 cfs from the beginning of 1996 through the end of 2007. Average flow rates at the Cibola Gage since January 2008 (through the end of 2022) have ranged from 2,224 to 18,751 cfs and averaged 7,632 cfs. This is a decrease of average flow rates of 1,299 cfs.

The implementation of the 2007 Interim Guidelines did not affect diversions at Imperial Dam, which meet water deliveries to water districts in the US and Mexico.

As stated in the 2007 FEIS, this reach is in a narrow alluvial fill valley with no adjacent irrigated land. The 2007 FEIS determined the 2007 Interim Guidelines would result in decreased groundwater elevations through this reach. (Refer to the groundwater discussion in the Parker Dam to Cibola Gage reach subsection for details.)

Imperial Dam to NIB

As stated in the 2007 FEIS, flows in the 26-mile reach from Imperial Dam to the Northerly International Boundary (NIB) are primarily comprised of releases from Imperial Dam, return flows from diversions at Imperial Dam, and inflows from the Gila River. The 2007 Interim Guidelines did not alter the operation of these diversions.

As stated in the 2007 FEIS, this reach is in the Yuma Valley groundwater basin and the South Gila Valley groundwater basin, which is small and bounded by rock. However, most water delivery from Imperial Dam to the NIB is via the All-American Canal. Based on the analyses performed in the 2007 FEIS, the 2007 Interim Guidelines were not anticipated to have affected groundwater levels in this reach. Therefore, Reclamation assumes that groundwater levels have remained the same since 2007.

NIB to SIB

As stated in the 2007 FEIS, flows in the 23.7-mile reach from the NIB to the SIB are limited. The Morelos Diversion Dam is 1.1 miles downstream of the NIB. Mexico owns, operates, and maintains the Morelos Diversion Dam for Mexico's delivery of flows. Water is diverted from the Morelos Diversion Dam into the Reforma Canal. Flows below the Morelos Diversion Dam in the river reach that extends down to the SIB consist of water in excess of Mexico's scheduled delivery resulting from flood control operations at Hoover Dam and other nontypical hydrologic events, seepage from the Morelos Diversion Dam, irrigation return flows, and groundwater accumulation.

The federal action evaluated in the 2007 FEIS anticipated that Mexico would continue to operate the Morelos Diversion Dam at the same elevation necessary to ensure the annual 1.5-maf delivery of water, per the 1944 Water Treaty under normal conditions (Mexico agreed to reductions and savings under low elevation reservoir conditions in Minute 323 to the 1944 Water Treaty). The 2007 Interim Guidelines do not affect Mexico's allotment.

The 2007 Interim Guidelines had the potential to impact flows attributed in excess of Mexico's scheduled delivery, since they affected the volume and frequency of flood control releases upstream of Mexico's diversion point. During the period 1974 through 2012, the average flows to Mexico in excess of scheduled deliveries was approximately 114,081 af. The Warren H. Brock Reservoir was completed in 2012 with the intent to conserve and reduce excess flows at the NIB. According to the Warren H. Brock Reservoir Conservation Summary Report (Summary Report) (Reclamation 2020c), prior to the completion of the Warren H. Brock Reservoir, the 10-year annual average (2003 through 2012) of flows to Mexico in excess was 82,853 af. Since the completion (through 2019), excess flows to Mexico decreased by approximately two-thirds, saving approximately 56,000 af per year. According to the Summary Report, the future volume of excess flows conserved is variable year-to-year based on hydrologic conditions, rainfall events, and other operational considerations along the lower Colorado River.

As described in the 2007 FEIS, this reach is in the large and deep Colorado River delta groundwater basin. In the upstream portion of the reach, groundwater provides surface flow to the river (gaining reach) due to the high groundwater elevation in the nearby irrigated lands. In the downstream portion of this reach, groundwater is recharged by the river (losing reach). Based on the analyses performed in the 2007 FEIS, the 2007 Interim Guidelines were not anticipated to affect gaining or losing sections of this reach.

3.6.2 Environmental Consequences

Methodology

This section examines the potential effects on hydrologic resources under the No Action Alternative (baseline condition) and the action alternatives. CRMMS, as described in **Section 3.3**, was used to analyze hydrologic resources across these alternatives. Modeling details for each alternative are described in **Section 3.3.8** and **Appendix C**, CRMMS Model Documentation.

Assumptions

(Please refer to **Section 3.3.8, Appendix C**, CRMMS Model Documentation, and **Appendix D**, Shortage Allocation Model Documentation, for a discussion pertaining to modeling assumptions.)

All statistics calculated are reflective of the hydrology scenarios and other assumptions used in modeling and they are not intended to suggest actual probabilities of any events occurring. However, it is meaningful to compare statistics across alternatives to differentiate performance.

Impact Indicators

For all alternatives evaluated, impacts are evaluated using output from the CRMMS model and described based on hydrologic conditions within the basin as follows:

- **Reservoir Elevations:** Changes to reservoir elevations are described based on a quantitative assessment of projected changes to reservoir water surface elevations for Lake Powell and Lake Mead monthly and on an end-of-water-year basis.
- **Reservoir Releases:** Changes to reservoir releases are described based on a quantitative assessment of projected changes to reservoir releases for Lake Powell and Lake Mead, including release volumes and timings.
- **River Flows:** Changes to river flows are described based on a quantitative assessment of changes in river flows for various reaches, including flow volumes and altered flow patterns. River flows follow the same pattern as reservoir releases.
- **Groundwater:** Changes to groundwater are described based on a qualitative assessment of potential changes to groundwater elevations, including relative changes in river stage and groundwater storage.

Issue 1: How would changes to operational activities affect reservoir elevations?

This section presents a comparison of the No Action Alternative, Action Alternative 1, and Action Alternative 2 in three metrics: monthly pool elevations, annual pool elevations, and percentages of traces below critical elevations at Lake Powell and Lake Mead.

Lake Powell

Summary of Alternatives Comparison

The conclusions in this section are drawn from analyses in three metrics: monthly pool elevations, percentages of traces below critical elevations, and annual pool elevations. Detailed comparisons of the alternatives follow in subsequent sections.

With respect to monthly Lake Powel pool elevations, remaining above elevation 3,490 feet is critical for preserving infrastructure ensuring Glen Canyon Dam continues to operate under its intended design for purposes of downstream water releases. Under the No Action Alternative, the median percentile of traces is at a minimum elevation of 3,505 feet in 2024 and at a maximum elevation of 3,555 feet in 2025. However, the range of modeled elevations under the No Action Alternative is wide with 30 to 35 percent of traces falling below an elevation of 3,490 feet throughout the period of analysis. Under Action Alternative 1 and Action Alternative 2, which show almost identical results to each other throughout time in all metrics, the medians of Lake Powell pool elevations range from a minimum of 3,520 feet in 2024 to a maximum of 3,576 feet in 2026. The percent of traces falling below 3,490 feet under the two action alternatives goes from 8 percent in 2024 to 0 percent in 2026. The median monthly pool elevation for the two action alternatives remain higher than the No Action Alternative throughout the period of analysis. The No Action Alternative has a higher likelihood of monthly pool elevations dropping below the critical elevation of 3,490 feet than either of the two action alternatives.

With respect to modeled end-of-water-year Lake Powell pool elevations, the distribution of elevations under the No Action Alternative results in a lower median and wider range than the action alternatives throughout the period of analysis. In 2024 and 2025, the median September 30th elevations range between 3,541 and 3,546 feet under the No Action Alternative and the interquartile ranges span a range of approximately 55 feet in 2024 to a range of 100 feet in 2026. The medians September 30th elevations for the action alternatives are approximately 3,555 feet in 2024 to 3,565 feet in 2026, and the interquartile ranges remain relatively consistent between 35 and 50 feet.

Throughout the period of analysis, the No Action Alternative results in a large number of traces falling below critical elevations; exhibits declining predictability in response to a wide range of potential hydrologic futures; and suggests lacking the ability to recover reservoir elevations above critical elevations once they are reached.

The operational modification included in Action Alternative 1 and Action Alternative 2 designed to protect Lake Powell elevation 3,500 feet is effective at minimizing instances of falling below 3,490 feet in 2024 and eliminating this outcome for all modeled traces by 2026. Actions would not take effect until 2024, which could result in traces ending 2023 and starting 2024 below 3,490 feet. The new Lower Elevation Release Tier created in both action alternatives provides the ability for Lake Powell elevations to gain a buffer against critical elevations under many modeled traces, thus reducing risk even further.

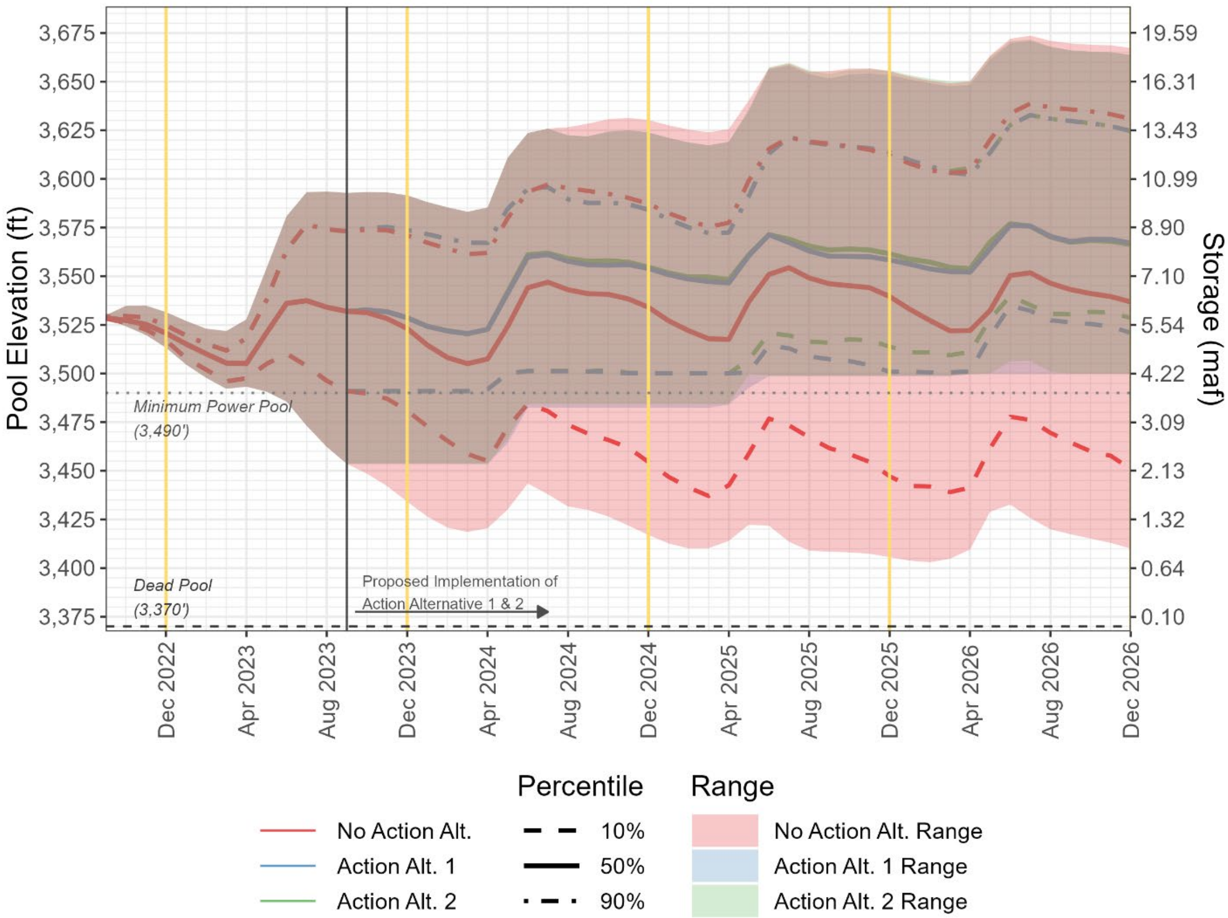
Monthly Pool Elevations

Figure 3-5 presents a comparison of the 10th, 50th, and 90th percentiles of modeled Lake Powell elevations for all alternatives as dashed, solid, and dash-dotted lines, respectively. It also shows "clouds" representing the full ranges of modeled elevations for all three alternatives through 2026.

The range of modeled Lake Powell elevations resulting from the No Action Alternative is shown by the red cloud in **Figure 3-5**, which spans from 3,417 to 3,631 feet in 2024, with fluctuations corresponding to seasonal reservoir levels. The bottom of the No Action Alternative cloud falls as low as 3,403 feet in 2026 and reaches as high as 3,674 feet in 2026, consistent with increasing uncertainty over time. The clouds for Action Alternative 1 (blue) and Action Alternative 2 (green) are nearly completely overlapping each other and are contained within the range of the No Action Alternative cloud. The clear distinction between the No Action Alternatives and the two action alternatives is that the lower boundaries of the ranges for the two action alternatives are considerably higher; in 2024, the minimum modeled elevation for Action Alternative 1 and Action Alternative 2 is 3,453 feet, or 36 feet higher than the lowest Lake Powell pool elevation modeled in the No Action Alternative. The minimum elevation of the action alternatives in 2026 is 3,500 feet, or 97 feet higher than the No Action Alternative. The ranges for the action alternatives stabilize at 3,500 feet because releases are calculated to explicitly protect that elevation.

In **Figure 3-5**, the 50th percentile, or median, of the modeled elevations for the No Action Alternative ranges between 3,505 and 3,547 feet in 2024, with minimums increasing slightly through 2026. The median elevations for the action alternatives are nearly identical, and they are approximately 5 to 20 feet higher than the median of the No Action Alternative throughout 2024.

Figure 3-5
Lake Powell End-of-Month Pool Elevations



By 2026, the median modeled pool elevations for the two action alternatives are 15 to 25 feet higher than the median of the No Action Alternative. The 90th percentiles of all three alternatives are similar, consistent with the overlap at the high ends of the three clouds.

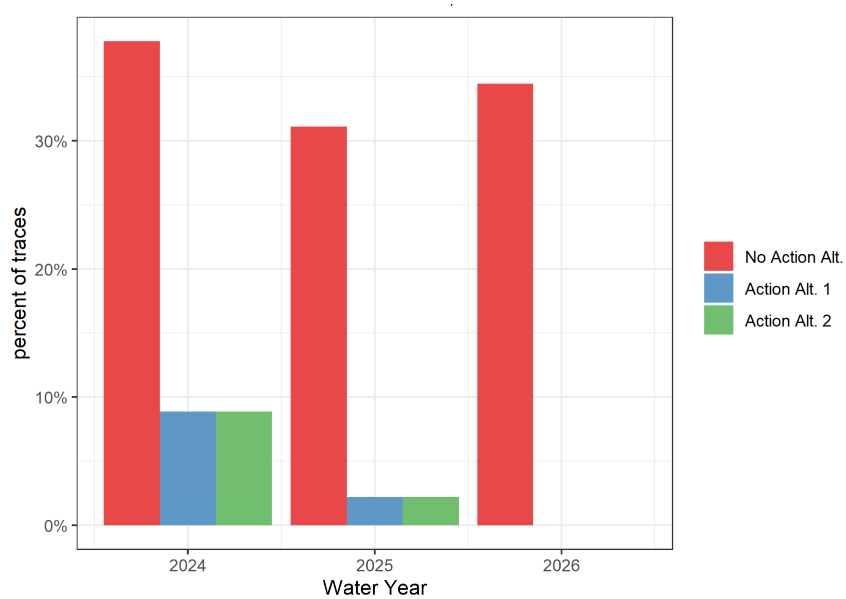
The differences in the 10th percentile lines in **Figure 3-5** show the potential impacts that the action alternatives could have in dry conditions. The No Action Alternative 10th percentile line falls below Lake Powell's minimum power pool (3,490 feet) in November of 2023, and it does not go above minimum power pool at any time through 2026. This means that 10 percent or more of the modeled traces were at or below minimum power pool throughout the analysis period under this alternative. The 10th percentiles of the modeled Lake Powell elevations for the two action alternatives are nearly identical through April 2025, and they do not ever go below minimum power pool, remaining constant at elevation 3,500 feet until they diverge slightly. By 2026, the 10th percentiles of both alternatives climb above 3,525 feet. The small differences between the action alternatives are due to the different modeling assumptions for potential DROA contributions; Action Alternative 2 includes an assumption for up to 500,000 af/year when Lake Powell is below 3,525 feet, which slightly increases Lake Powell's elevations.

Percentages of Traces Below Critical Elevations

Figure 3-6 shows the percent of modeled traces that fell below Lake Powell elevation 3,490 feet at any time during a year for the period of analysis. Remaining above 3,490 feet is critical for protecting infrastructure.

Figure 3-6 shows that in 2024, 38 percent of the modeled traces fall below Lake Powell elevation 3,490 feet at some point during the operating year under the No Action Alternative, while only 9 percent of traces do so under the two action alternatives. In 2025 and 2026, the No Action Alternative results in 31 percent and 34 percent of traces falling below 3,490 feet, respectively, while 2 percent and 0 percent of the action alternatives' traces do so.

Figure 3-6
Lake Powell Minimum Operating Year Elevation, Percent of Traces Less than Elevation 3,490 feet

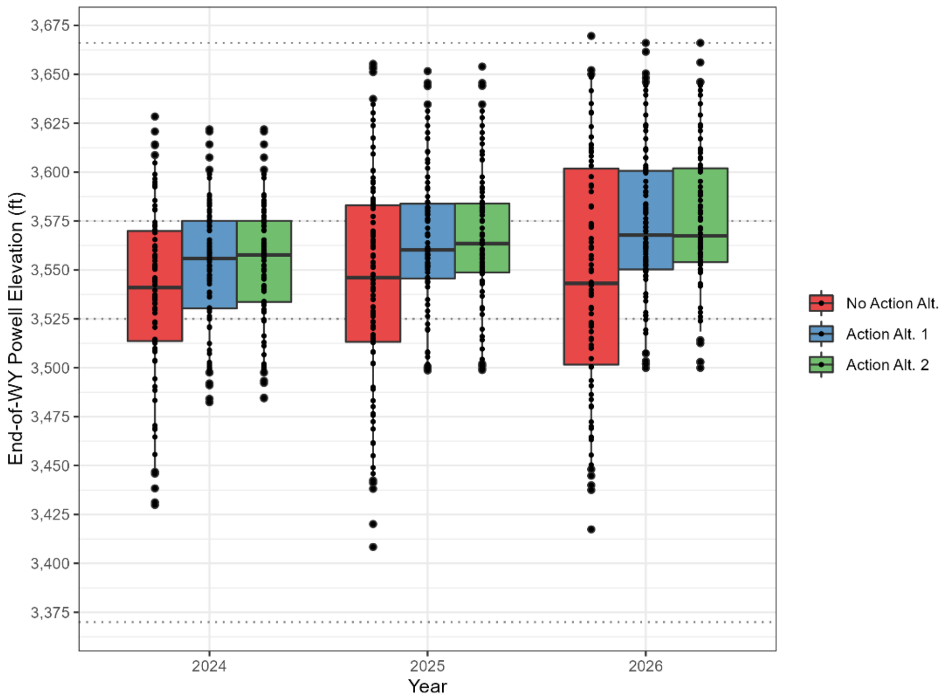


Annual Pool Elevations

Figure 3-7 shows the distributions of modeled Lake Powell elevations on September 30 in 2024, 2025, and 2026. Each dot is the end-of-water year elevation produced by a single hydrologic trace. Dots may be plotted on top of one another. The top and bottom of each box captures the 25th to 75th percentile of the modeled elevations, the whiskers extend to the 5th and 95th percentiles, and the outliers are represented as dots beyond these lines.

The No Action Alternative boxplots in **Figure 3-7** show how a wide range of modeled end-of-Water Year pool elevations at Lake Powell are distributed; while the medians of the elevations are relatively stable around 3,530 to 3,540 feet, the interquartile ranges increase through time as do the whiskers and outliers. In comparison, the action alternatives have median end-of-water-year elevations approximately 15 feet higher in 2024 and 2025 and approximately 25 feet higher in 2026.

Figure 3-7
Powell End-of-Water Year Pool Elevations



The interquartile and full ranges for the two action alternatives are smaller than those of the No Action Alternative, with Action Alternative 2 having slightly higher modeled elevation ranges due to the different assumptions for potential DROA contributions.

Lake Mead

Summary of Alternatives Comparison

The conclusions in this section are drawn from analyses in three metrics: monthly pool elevations, percentages of traces below critical elevations, and annual pool elevations. Detailed comparisons of the alternatives follow in subsequent sections.

With respect to all metrics, the differences between the No Action Alternative and the two action alternatives vary in 2024 when compared to the differences in 2025 and 2026. In 2024, modeling of the driest hydrologic traces with Action Alternative 1 and Action Alternative 2 result in lower Lake Mead elevations than the No Action Alternative. This discrepancy is the result of both Lake Powell and Lake Mead modeled operations. The modeled Lake Powell operations in the action alternatives result in projected releases below 7.0 maf, which occur immediately in 2024 in the driest traces, while releases from the No Action Alternative do not become constrained by Glen Canyon Dam infrastructure limitations until later in the period of analysis (refer to *Issue 2*). Modeled Lower Basin total shortages and contributions are constrained to 2.083 maf in 2024; however, modeled Lower Basin shortages and contributions increase in 2025 and 2026 when larger additional shortages are modeled below elevation 1,040 feet. As a result, through 2026 the modeled action alternatives are significantly more effective in all traces than the No Action Alternative.

In terms of monthly Lake Mead pool elevations, the bottoms of the modeled ranges under the action alternatives decline more steeply than the No Action Alternative in 2024 and the first half of 2025 with Action Alternative 1 reaching 895 feet, or dead pool (the elevation at which Lake Mead can no longer regularly release water), in April 2025 before recovering for the next 10 months. Action Alternative 2 falls to dead pool for three months in 2026 and recovers, while the No Action Alternative reaches dead pool in January 2026 and it does not recover for the rest of the period of analysis. The median elevations across the three alternatives do not exhibit such large differences in 2024, and in April 2025 the relative performance between the action alternatives and the No Action Alternative switches, and by 2026 the peak median Lake Mead elevations for the action alternatives is approximately 1,040 feet and the peak for the No Action Alternative is approximately 1,015 feet.

Risks of falling below critical elevations exhibit similar patterns over the period of analysis across all thresholds analyzed: in 2024 the percentages of modeled traces falling below the specific Lake Mead elevation threshold are between 0 and 5 percent higher in the action alternatives compared to the No Action Alternative; in 2025 percentages of traces are generally increasing for the No Action Alternative and decreasing for the action alternatives; and by 2026 the percentages of traces violating a critical threshold under the No Action Alternative are significantly higher than the percentages of both action alternatives. The most important result is that in 2026, 8 percent of traces under the No Action Alternative approached dead pool while only 1 percent did so under the two action alternatives. At dead pool, only flows that reach the reservoir, less any diversions or losses, could be released downstream through the Glen Canyon Dam. Below this elevation water could not be released through the Glen Canyon Dam via gravity.

A comparison of modeled December 31st Lake Mead pool elevations across alternatives shows that in 2024 the action alternatives exhibit slightly lower medians than the No Action Alternative and more variability. In 2025 and 2026, the median elevations of the action alternatives are approximately 20 and 30 feet higher, respectively, than the medians of the No Action Alternative. In 2026, all of the alternatives have similar magnitudes of variability, but the distributions of elevations under the action alternatives are shifted higher. The median pool elevation of the No Action Alternative in 2026 is approximately 1,010 feet and the medians of the action alternatives are approximately 1,040 feet.

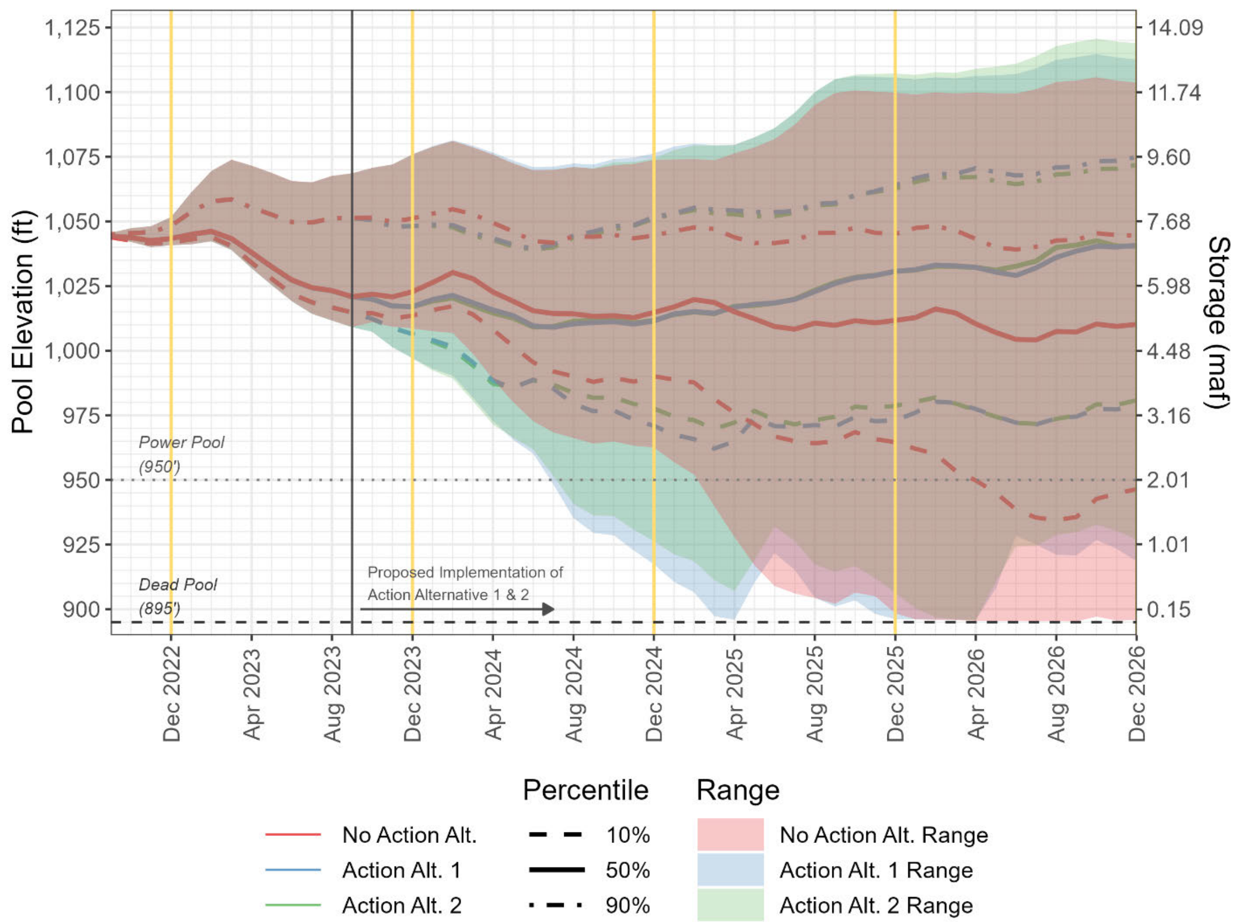
Throughout the period of analysis, the No Action Alternative exhibits generally declining Lake Mead elevations and significant increases in risks of falling below critical elevations.

In 2024, the driest modeled traces result in significant declines in Lake Mead elevations under Action Alternative 1 and Action Alternative 2 as a result of immediate and in some cases significant reductions in releases from Lake Powell. However, in the majority of modeled traces, elevations stabilized and increased in 2025 and 2026. The additional shortage reductions were effective at greatly reducing the risk of reaching the most critical elevations by 2026.

Monthly Pool Elevations

Figure 3-8 presents a comparison of the 10th, 50th, and 90th percentiles of modeled Lake Mead elevations for all alternatives as dashed, solid, and dash-dotted lines, respectively. It also shows "clouds" representing the full ranges of modeled elevations for all three alternatives through 2026.

Figure 3-8
Lake Mead End-of-Month Pool Elevations



The range of modeled Lake Mead pool elevations resulting from the No Action Alternative is shown by the red cloud in **Figure 3-8**, which spans from 963 to 1,081 feet in 2024, with fluctuations corresponding to seasonal reservoir levels. The bottom of the No Action Alternative cloud falls to 898 feet in 2025 and it reaches 895 feet, or dead pool, in January 2026 with essentially no recovery. At dead pool, only flows that reach the reservoir, less any diversions or losses, could be released downstream through Glen Canyon Dam. Below this elevation, water could not be released through dam via gravity. The high range of Lake Mead elevations under the No Action Alternative goes from 1,081 feet in 2024 to 1,106 feet in 2026. This increasing range is consistent with increasing uncertainty over time. The clouds for Action Alternative 1 (blue) and Action Alternative 2 (green) are similar throughout the period of analysis, though when differences occur, it is Action Alternative 2 showing slightly higher modeled elevations than Action Alternative 1. This occurs because of the different assumptions for potential DROA contributions modeled under Action Alternative 2, which sometimes result in larger releases to Lake Mead, and the distribution of shortages among Lower Basin users can have minor effects on elevations. The most significant difference between the ranges across all alternatives is that under the driest hydrology, the action alternatives drop more steeply than the No Action Alternative in 2024, with Action Alternative 1 reaching dead pool in

April 2025 (but recovering the next month). The action alternatives decline more steeply because operations explicitly designate annual releases below 6.0 maf from Glen Canyon Dam to protect elevation 3,500 feet at Lake Powell. Both action alternatives eventually reach dead pool, but they recover for some periods while the No Action Alternative does not. The periods of recovery in 2025 and 2026 are in part due to the additional shortage volumes below 1,035 feet that take effect in these years. At the high end of the range of modeled Lake Mead pool elevations, the action alternatives show slightly greater increases than the No Action Alternative through 2026.

In **Figure 3-8**, the median of the modeled Lake Mead elevations for the No Action Alternative ranges between 1,013 feet and 1,030 feet in 2024 and it exhibits a downward trend throughout the period of analysis. The medians of the action alternatives are nearly identical and in 2024 they range from 1,009 feet to 1,020 feet. While this is lower than the range for the No Action Alternative, the median modeled elevations for the action alternatives exhibit an upward trend that begins in late 2024 and continues through 2026 due to the increases in shortages that take effect after 2024. In December 2026, the median elevations under the two action alternatives are at 1,041 feet and the median under the No Action Alternative is at Lake Mead elevation 1,010 feet.

For the 90th percentiles of modeled Lake Mead elevations in **Figure 3-8**, the No Action Alternative and the action alternatives show a similar range in 2024, and the action alternatives trend upward while the No Action Alternative has a slight downward trend. The 10th percentiles of elevations for the two action alternatives are consistently lower than the 10th percentile of the No Action Alternative in 2024, but as with the medians, those relative positions switch in 2025 and the action alternatives stabilize around 975 feet through the remainder of the period of analysis while the No Action Alternative falls to 934 feet in 2026.

Percentages of Traces Below Critical Elevations

Figure 3-9 shows the percent of modeled traces that fell below Lake Mead elevation 1,020 feet at any time during a year for the period of analysis. Elevation 1,020 feet was identified as a critical protection elevation in the 2019 DCPs.

Figure 3-9 shows that in 2024, 68 percent of the modeled traces under the No Action Alternative fall below Lake Mead elevation 1,020 feet, and slightly more traces do so under the two action alternatives: 71 percent under Action Alternative 1 and 72 percent under Action Alternative 2. (While Action Alternative 2 generally performs slightly better than Action Alternative 1 for reasons described above, very small elevation differences in a single month due to shortage distributions can push traces into or out of the categories in this metric.) Under the No Action Alternative, the percent of traces increases through 2026, at which point 77 percent of traces fall below 1,020 feet. The percentages of traces decline identically through 2026 under both action alternatives: in 2025, 64 percent of traces fall below 1,020 feet and in 2026, 48 percent do so.

Figure 3-9
Lake Mead Minimum Annual Elevation, Percent of Traces Less than Elevation 1,020 feet

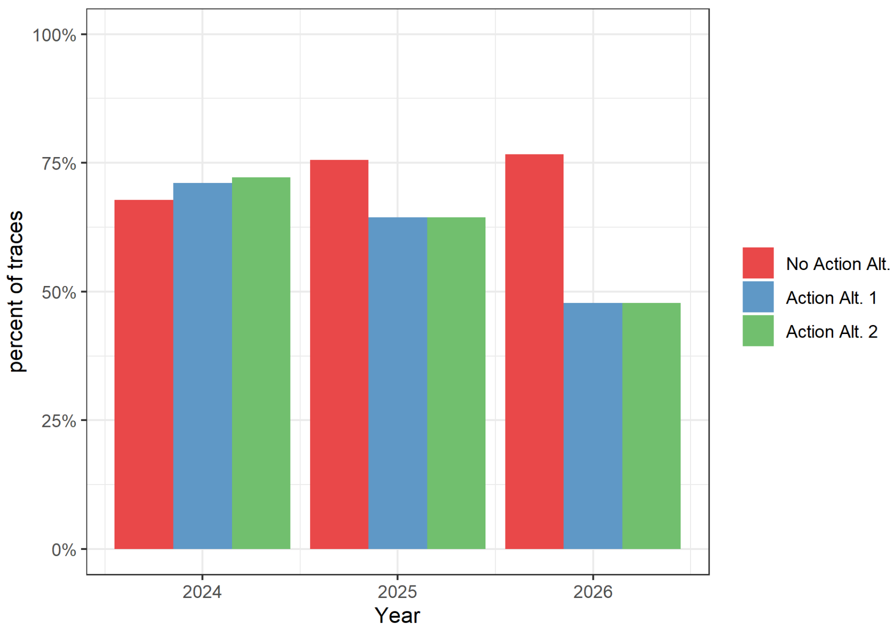


Figure 3-10 shows the percent of modeled traces that fell below Lake Mead elevation 950 feet at any time during a year for the period of analysis. Elevation 950 feet is a critical elevation because it is the lowest elevation at which Hoover Dam can generate hydropower.

As shown in **Figure 3-10**, the No Action Alternative does not result in any traces falling below 950 feet at Lake Mead at any time during 2024, while under Action Alternative 1, 6 percent of traces do and under Action Alternative 2, 3 percent of traces do. In 2025, the alternatives have similar percentages of traces falling below 950 feet – 9 percent for the No Action Alternative and Action Alternative 1 and 8 percent for Action Alternative 2. In 2026, the percentage reaches 14 percent for the No Action Alternative while the Action Alternative 1 and Action Alternative 2 percentages decline to 7 percent and 4 percent, respectively.

Figure 3-11 shows the percent of modeled traces that fell below Lake Mead elevation 900 feet at any time during a year for the period of analysis. Elevation 900 feet is a critical elevation because it is approaching 895 feet, which is dead pool at Lake Mead.

Figure 3-11 shows that in 2024, no traces in any alternatives approach dead pool in Lake Mead. In 2025, 1 percent of traces under the No Action Alternative and 2 percent under Action Alternative 1 approach dead pool. In 2026, 8 percent of traces under the No Action Alternative approach dead pool and 1 percent of traces in both action alternatives do so.

Figure 3-10
Lake Mead Minimum Annual Elevation, Percent of Traces Less than Elevation 950 feet

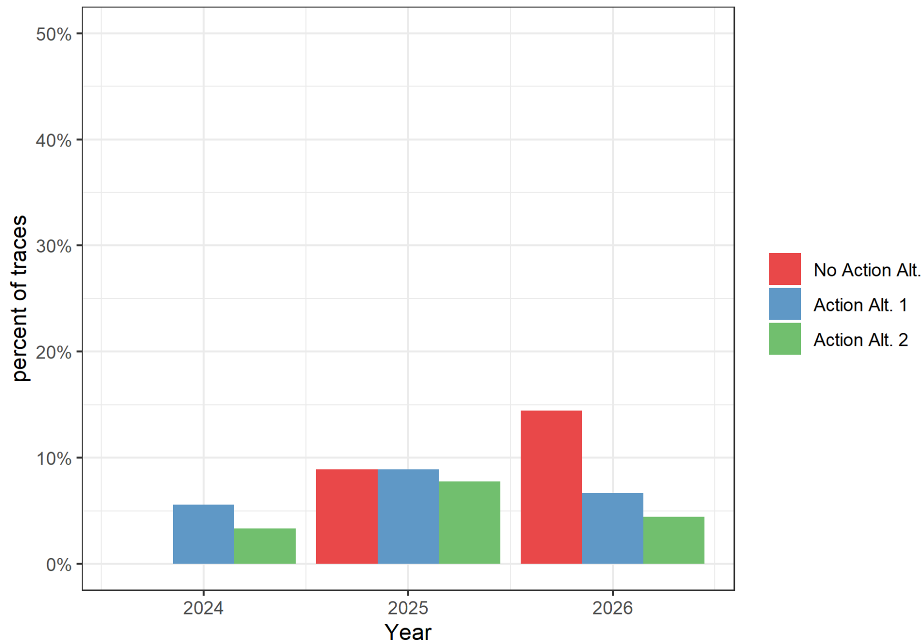
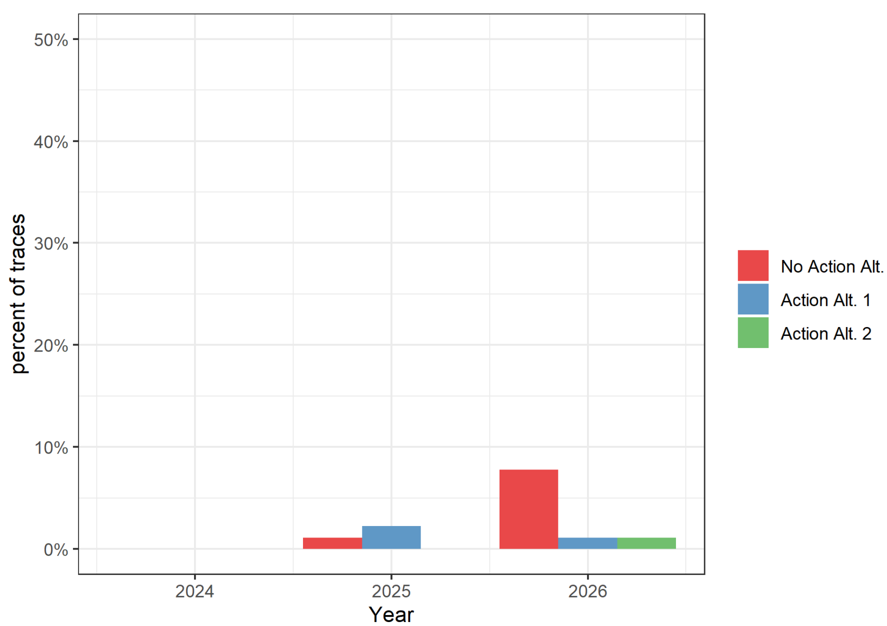


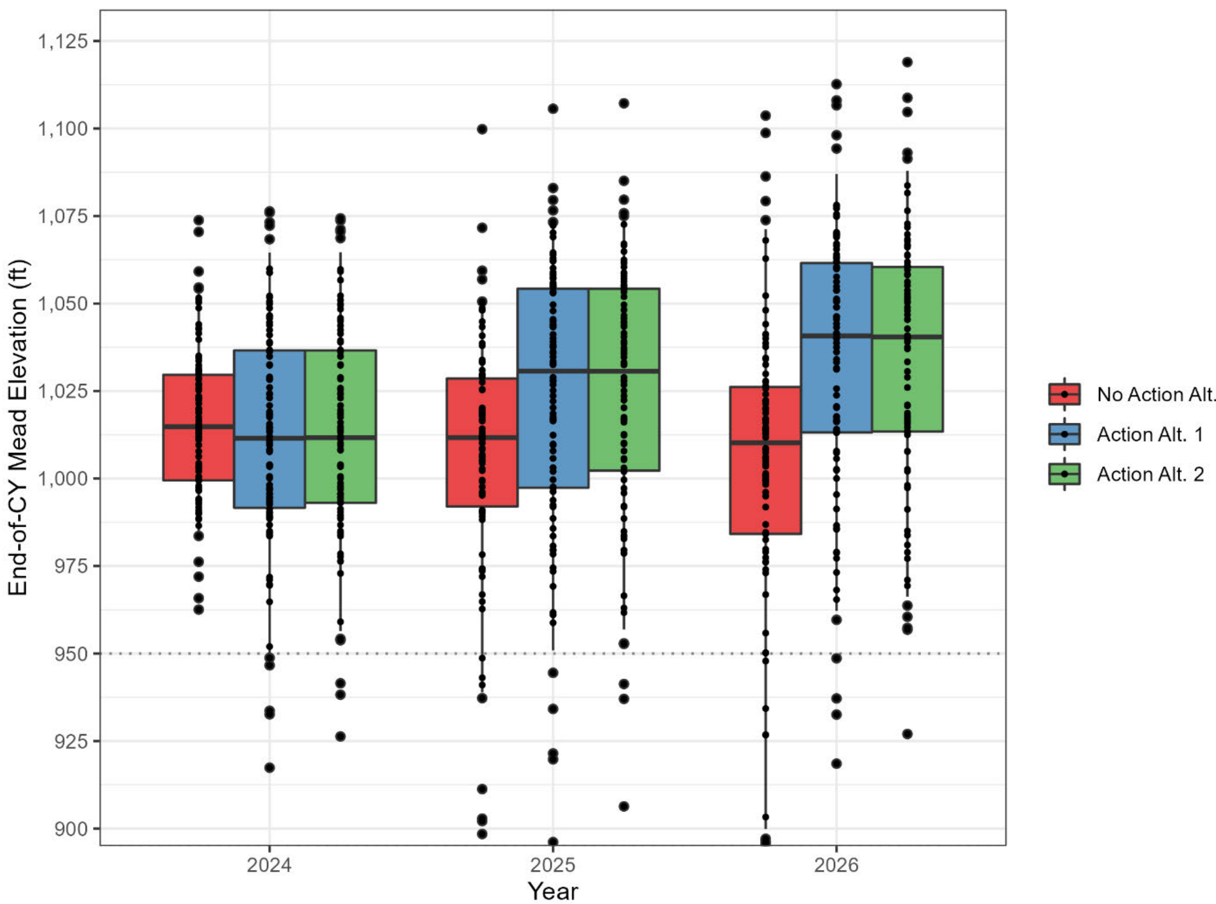
Figure 3-11
Lake Mead Minimum Annual Elevation, Percent of Traces Less than Elevation 900 feet



Annual Pool Elevations

Figure 3-12 shows the distributions of modeled December 31st Lake Mead elevations in 2024, 2025, and 2026. This end-of-calendar-year elevation is used to determine shortage conditions for the following calendar year. Each dot is the end-of-calendar year elevation produced by a single hydrologic trace. Dots may be plotted on top of one another. The top and bottom of each box captures the 25th to 75th percentile of the modeled elevations, the whiskers extend to the 5th and 95th percentiles, and the outliers are represented as dots beyond these lines.

Figure 3-12
Mead End-of-Calendar-Year Elevation



The No Action Alternative boxplots in **Figure 3-12** show how a wide range of modeled end-of-calendar-year Lake Mead elevations are distributed from the minimum at 963 feet to the maximum of 1,074 feet in 2024 and a median of 1,015 feet. The median elevations decline slightly through 2026, as do the interquartile ranges, but the high and especially the low ends of the distributions of traces expand. The increasing frequency of lower extremes occurs because the release capacity of Glen Canyon Dam when Lake Powell is below 3,490 feet becomes constrained. The two action alternatives have similar distributions of modeled Lake Mead elevations from 2024 through 2026, with the slight discrepancies due mostly to the impacts of different modeling assumptions for the potential DROA contributions represented in Action Alternative 2 that can increase Lake Powell's release volumes. Compared to the 2024 distribution of elevations under the No Action Alternative, the action alternatives produced a wider range, particularly at the low end due to the explicit allowance of Lake Powell releases below 7.0 maf (whether determined by the Lower Elevation Release Tier or as protection of elevation 3,500 feet). The medians of the action alternatives are at approximately 1,011 feet, or 4 feet lower than the median of the No Action Alternative. In 2025 and 2026, the medians of the action alternatives' modeled elevations increase significantly – by over 20 feet in 2025 and an additional 10 feet in 2026 when the medians are approximately 1,040 feet. The ranges of modeled elevations increase slightly in 2025 before contracting and shifting up in 2026.

Lake Mohave and Lake Havasu

Summary

Lake Mohave and Lake Havasu are operated on a rule curve and have target end-of-month elevations. This manner of operation will continue in the future and it would apply to operations under any of the action alternatives. Therefore, future Lake Mohave and Lake Havasu elevations would be expected to be similar between the action alternatives and the No Action Alternative.

Cumulative Effects

Implementation of one of the Glen Canyon Dam/Smallmouth Bass flow options would not result in annual or monthly changes to reservoir levels in Lake Powell or Lake Mead. The operating tiers established by this SEIS will inform flow rates and volumes if flow options are implemented. Therefore, no additive cumulative effects would occur on reservoir levels due to proposed operational changes evaluated in the EA.

Issue 2: How would changes to operational activities affect reservoir releases?

This section presents a comparison of reservoir release volumes under the No Action Alternative, Action Alternative 1, and Action Alternative 2 in various metrics, including reservoir operating tiers, annual release volumes, and monthly release volumes. All statistics calculated are reflective of the hydrology scenarios and other assumptions used in modeling and are not intended to suggest actual probabilities of any events occurring. However, it is meaningful to compare statistics across alternatives to differentiate performance.

Glen Canyon Dam

Summary of Alternatives Comparison

The conclusions in this section are drawn from analyses in four metrics: Lake Powell operational tiers, operating year Glen Canyon Dam Releases, monthly Glen Canyon Dam releases, and the 10-year running sum of Lees Ferry flows. Detailed comparisons of the alternatives follow in subsequent sections.

Throughout the period of analysis, the action alternatives result in more traces shifting into higher operational tiers than the No Action Alternative: in 2026, 21 percent of traces modeled under the No Action Alternative operate in either the Upper Elevation Balancing Tier or Equalization Tier, while approximately 40 percent of traces under the action alternatives operate in these tiers. While this is partially because the action alternatives assume that the 480,000 af stored in Lake Powell instead of Lake Mead since 2022 is no longer operationally neutral, the majority of this difference is the result of increasing elevations at Lake Powell.

The upward shifts in operational tiers are reflected in operating year Glen Canyon Dam releases, which show that the median modeled release volumes under all alternatives are within 500,000 af of each other throughout the period of analysis, ranging between 7.0 and 7.7 maf. The differences between the No Action Alternative and the action alternatives are larger in the bottom half, and especially the bottom 25 percent, of the distributions in 2024 and 2025: under the No Action Alternative, the driest 25 percent of modeled traces result in releases that range from 5.9 to 7.0 maf in 2024 and 5.1 to 7.48 maf in 2025; under the action alternatives, the ranges are similar to each other spanning approximately 3.6 to 6.0 maf in 2024 and approximately 3.0 to 6.2 maf in 2025. (Releases below 6.0 maf are required to protect elevation 3,500 feet.) In 2026, the ranges of modeled operating year releases from Glen Canyon Dam all alternatives are similar, though the inclusion of different assumptions for potential DROA contributions in Action Alternative 2 increases the releases under the driest modeled traces.

The differences between modeled monthly Glen Canyon Dam releases under the No Action Alternative and the action alternatives have two different patterns. In the first half of the operating year, releases under the action alternatives are lower at the medians and have greater low-end variability than the No Action Alternative. During the second half of the operating year, median releases under the action alternatives are higher than median releases under the No Action Alternative and the variability is greater in both the interquartile and full ranges. This is due to how the Lower Elevation Release Tier in the action alternatives is modeled: start in October with a 6.0 maf release pattern and then adjust upward in April if warranted by runoff conditions. Throughout the operating year, approximately 5 to 10 percent of the traces modeled under the two action alternatives fall below the estimated daily minimum flow threshold specified by LTEMP. Under the No Action Alternative, fewer than 5 percent of traces fall below the threshold. However, when Lake Powell is below 3,490 feet, as it is in more than 30 percent of traces every year under the No Action Alternative, monthly and daily releases from Glen Canyon Dam are highly uncertain.

With respect to the modeled 10-year running sums of flows at Lees Ferry gage, the medians under all alternatives decline over the period of analysis. The median flows of the action alternatives are always lower than the medians of the No Acton Alternative, with the differences increasing over time. In 2024, the median flow volumes under the No Action Alternative were just under 85 maf and the medians of the action alternatives were approximately 84 maf. In 2026, the median of the No Action Alternative is 82.9 maf, and the medians under the action alternatives are approximately 81.5 maf. Twenty-five percent of modeled 10-year Lees Ferry gage flows are below 82.3 maf under all alternatives in 2026, and under Action Alternative 1 and Action Alternative 2, 10 percent and 5 percent, respectively, are below 75 maf.

Lake Powell Operating Tiers

Figure 3-13 shows the percent of modeled traces that were within each operational tier for the period of analysis. (Note that the Mid-Elevation Release Tier and the Lower Elevation Balancing Tier of the No Action Alternative are encompassed and replaced by one tier in the action alternatives, the new Lower Elevation Release Tier.)

Figure 3-13
Lake Powell - Percent of Modeled Traces within each Operational Tier

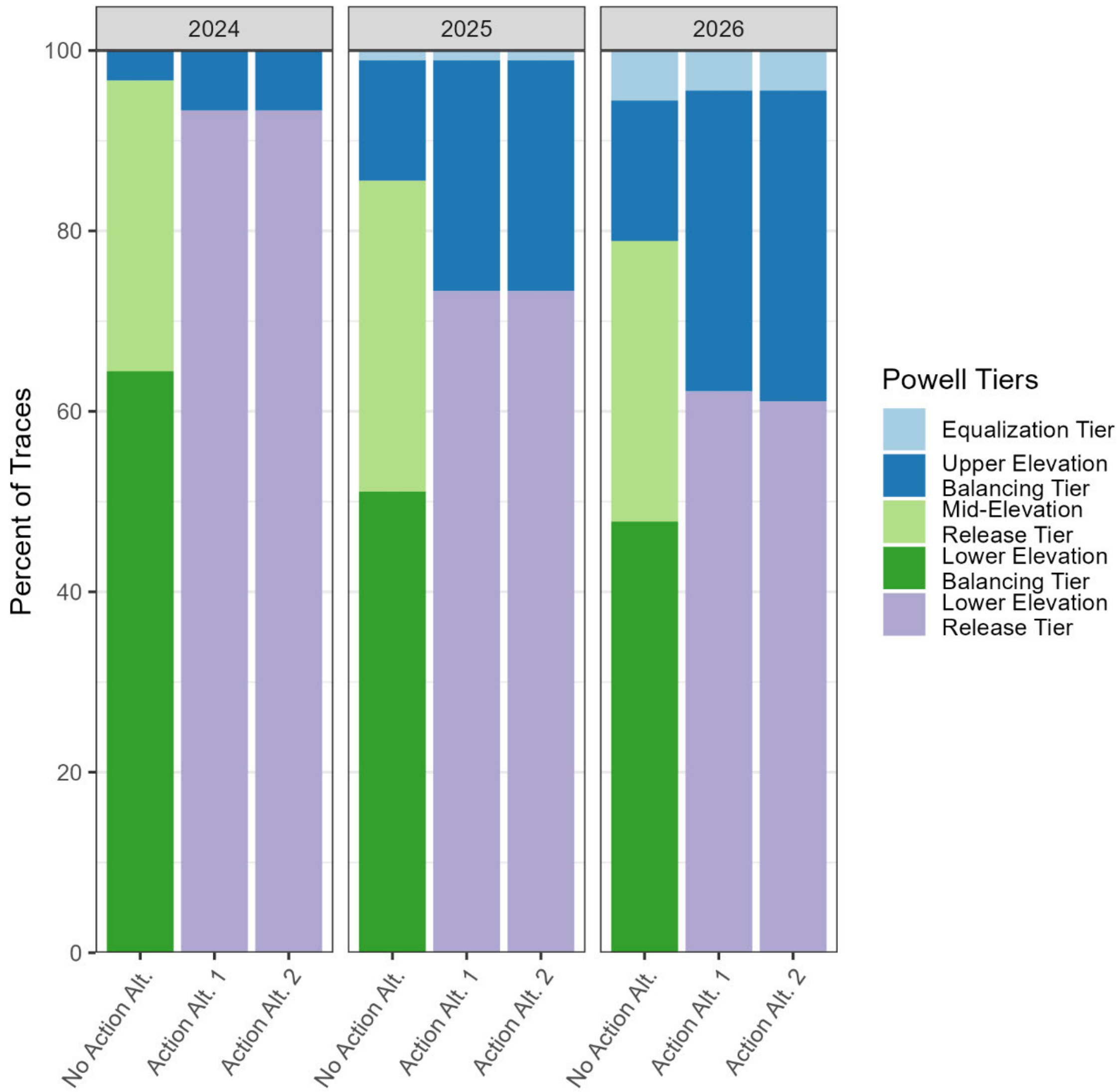


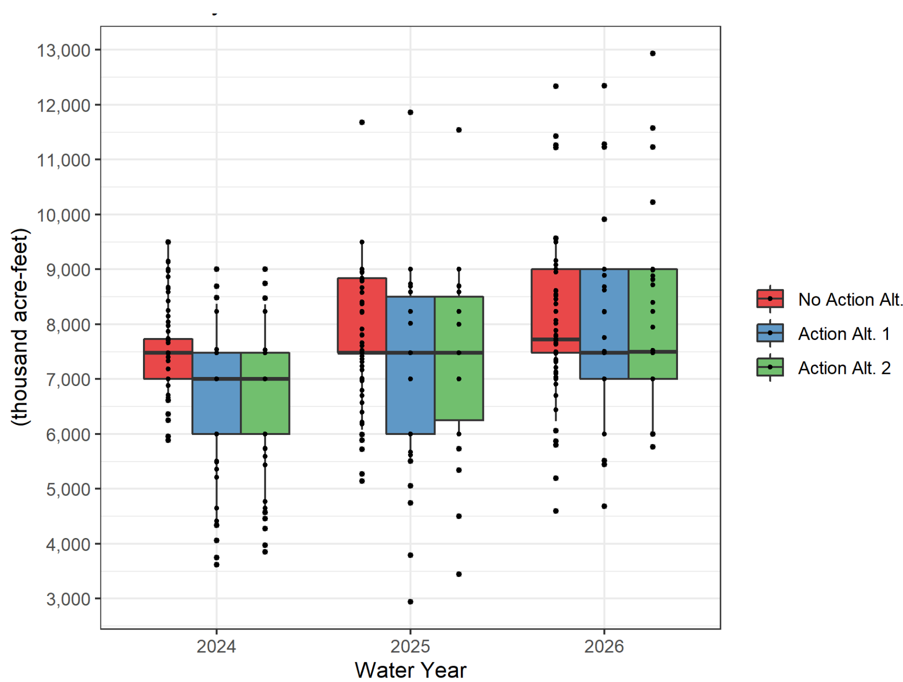
Figure 3-13 shows that in 2024, in the No Action Alternative, 64 percent of modeled traces operated in the Lower Elevation Balancing Tier, in which annual releases range from 7.0 maf to 9.5 maf (unless infrastructure limitations below Lake Powell elevation 3,490 feet reduce the volume that can be released), and the number of traces in this tier decreases to 48 percent through 2026. Approximately 30 percent of traces under the No Action Alternative are in the Mid-Elevation Release Tier in all years, in which the release is either 7.48 or 8.23 maf. The percent of traces in the Upper Elevation Balancing Tier, in which releases range from 7.0 to 9.0 maf, increases from 3 percent in 2024 to 16 percent by 2026. By 2026, 6 percent of traces operate in the Equalization Tier for the No Action Alternative. This shift toward higher tiers is a result of the wide range of hydrology traces used and it is reflected in the elevations seen in **Figure 3-5**.

Figure 3-13 shows that Action Alternative 1 and Action Alternative 2 have identical distributions across tiers until 2026. In 2024, 6 percent of modeled traces are in Upper Elevation Balancing Tier. (The elevations delineating this tier are common among all alternatives, and the reason there are more traces operating in it for the action alternatives is that they eliminate operational neutrality for 480,000 af, meaning that it is included in Lake Powell's tier determination in the action alternatives while it is treated "as if" it is in Lake Mead for tier determinations in the No Action Alternative.) In 2024, 93 percent of traces for the action alternatives operate in the new Lower Elevation Release Tier, in which annual releases range from 6.0 to 8.23 maf (unless releases are further reduced to protect Lake Powell elevation 3,500 feet), and, similarly to the No Action Alternative, the distribution of modeled traces shifts to higher tiers through the period of analysis. In 2026, Action Alternative 1 has 33 percent of traces in Upper Elevation Balancing Tier and Action Alternative 2 has 34 percent in that tier, and both have 4 percent in the Equalization Tier. The slight difference in the modeled projections of the two action alternatives is due to the different assumptions for potential DROA contributions in Action Alternative 2 that affect some traces. Both action alternatives have approximately twice as many traces as the No Action Alternative in the Upper Elevation Balancing Tier in 2025 and 2026.

Annual Release Volumes

Figure 3-14 shows the distributions of modeled operating year release volumes from Glen Canyon Dam in 2024, 2025, and 2026. This volume is determined by the operating tiers, which were analyzed in the previous section. Each dot is the operating year releases produced by a single hydrologic trace. Dots may be plotted on top of one another. The top and bottom of each box captures the 25th to 75th percentile of the modeled elevations, the whiskers extend to the 5th and 95th percentiles, and the outliers are represented as dots beyond these lines.

Figure 3-14
Glen Canyon Dam Operating Year Releases



The boxplots for the No Action Alternative in **Figure 3-14** show that median of modeled release from Glen Canyon Dam was 7.48 maf in 2024 and that 9 percent were lower than 7.0 maf, indicating that infrastructure limitations below Lake Powell elevation 3,490 feet impacted releases in these traces. In 2025 and 2026, median modeled releases from Glen Canyon Dam under the No Action Alternative were 7.48 and approximately 7.70 maf, respectively, and 13 percent and 9 percent of traces released less than 7.0 maf, respectively. Throughout the period of analysis, the minimum releases under the No Action Alternative decrease from approximately 5.9 maf in 2024 to 4.6 maf in 2026.

The distributions of operating year releases for the two action alternatives shown in **Figure 3-14** show nearly identical distributions, with the minor variations due to the different modeling assumptions for potential DROA contributions in Action Alternative 2 that results in higher releases in some traces. In 2024, the medians of the modeled releases for the two action alternatives are 7.0 maf, and 88 percent of releases are 6.0 maf or higher. The remaining 12 percent of modeled releases range from 3.6 to 5.5 maf under Action Alternative 1 and 3.8 to 5.7 maf under Action Alternative 2. Median modeled annual Glen Canyon Dam releases increase to 7.48 maf in 2025 and 2026 under both action alternatives, with increased variability around the median in both interquartile ranges and outliers. Minimum releases are lowest in 2025, when Action Alternative 1 results in a release of 2.9 maf from Glen Canyon Dam and Action Alternative 2 results in a 3.4 maf release to protect 3,500 feet at Lake Powell. The ranges of releases for both action alternatives increase significantly in 2026, when they are similar to the range of annual releases under the No Action Alternative.

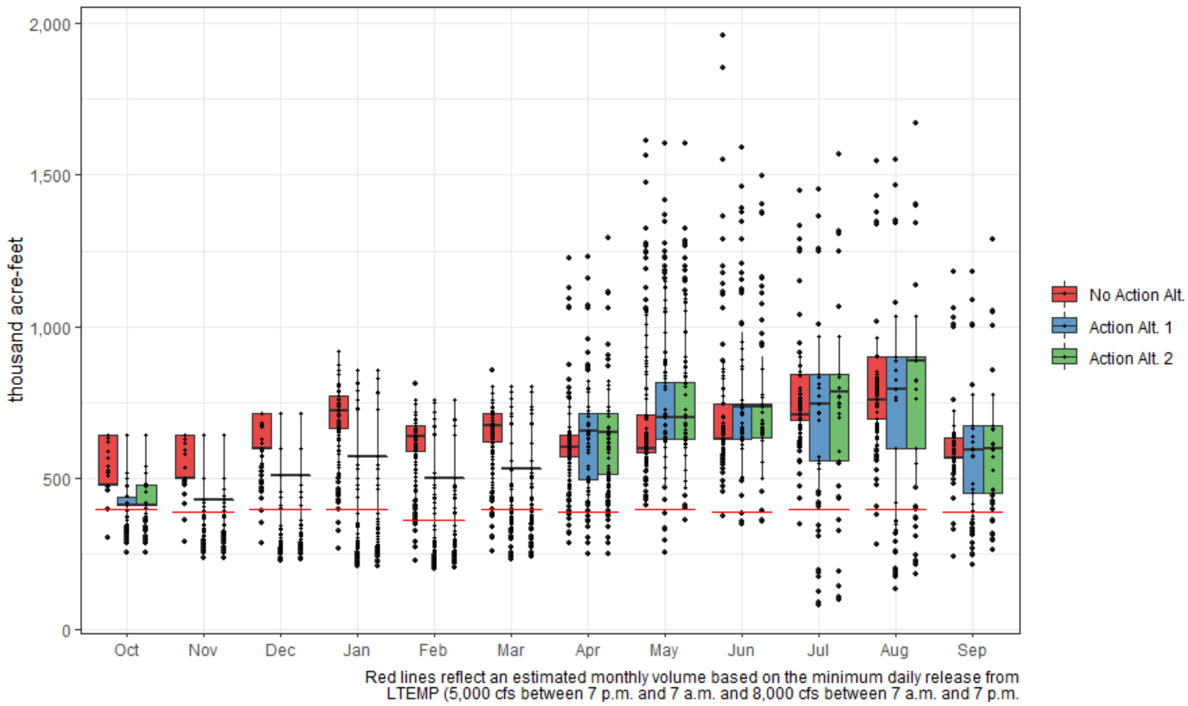
Monthly Release Volumes

Figure 3-15 shows the distributions of modeled monthly release volumes in operating years 2024, 2025, and 2026, oriented to the operating year (October through September) on which Lake Powell operates. These volumes are estimates of how the annual volumes described in the previous section would be divided in consideration of authorities affecting sub-annual releases (hourly, daily, monthly, and experimental releases) from Glen Canyon Dam. See **Section 3.3** for more information about these modeling assumptions.

Each dot in **Figure 3-15** represents the monthly releases produced by a single hydrologic trace. Dots may be plotted on top of one another. The top and bottom of each box captures the 25th to 75th percentile of the modeled releases and the whiskers extend to the 5th and 95th percentiles, with outliers represented as dots beyond these lines. The red lines reflect the estimated total monthly volume that would be released if Glen Canyon Dam met the minimum daily releases specified in LTEMP (5,000 cfs between 7 p.m. and 7 a.m. and 8,000 cfs between 7 a.m. and 7 p.m.).

The boxplots of monthly modeled Glen Canyon Dam release volumes under the action alternatives in **Figure 3-15** demonstrate the impacts of the new Lower Elevation Release Tier. For the first half of the operating year, the action alternatives have lower releases than the No Action Alternative, mostly because 60 to 95 percent of the traces under that action alternatives operate in the new Lower Elevation Release Tier, which is modeled to start the year with a 6.0 maf release pattern with an optional upward April adjustment based on hydrologic conditions. This is also the cause of the wide variability from April to September under the action alternatives.

Figure 3-15
Lake Powell Monthly Release, Operating Years 2024–2026



From April through September, **Figure 3-15** shows that the differences in median modeled monthly releases from Glen Canyon Dam are reversed: medians of the action alternatives are higher than those of the No Action Alternative, though the magnitudes vary across months because of large variability in the releases under the action alternatives. The monthly releases on the lower end of the distributions under the action alternatives tend to be lower or significantly lower than those under the No Action Alternative.

Per **Figure 3-15**, 5 percent or fewer traces modeled under the No Action Alternative exceed the estimated daily minimum flow target in every month. However, when Lake Powell is below 3,490 feet, as it is in more than 30 percent of traces every year under the No Action Alternative, monthly and daily release from Glen Canyon Dam are highly uncertain. Under the two action alternatives, more than 10 percent of traces fall below the target during the first half of the operating year due to the 6.0 maf release pattern. In the second half of the operating year, fewer than 5 percent of traces modeled under Action Alternative 2 fall below the target, and under Action Alternative 1, between 5 and 10 percent of the traces fall below the estimated minimum daily flow target volume.

Ten-Year Lees Ferry Gage Flows

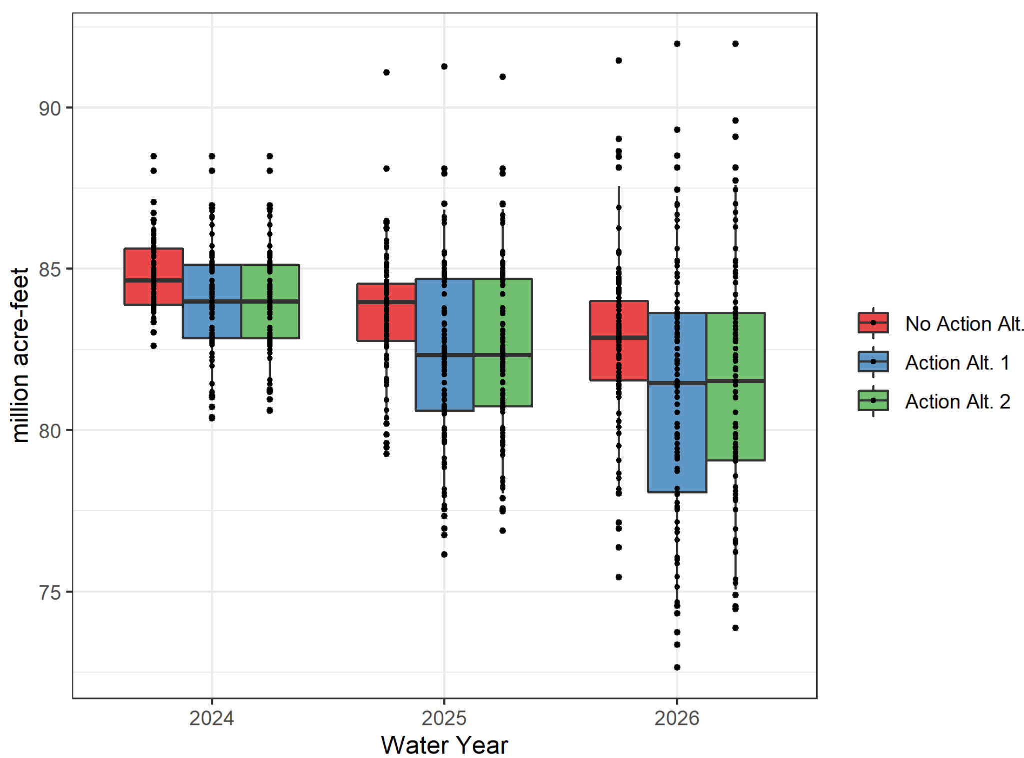
Figure 3-16 shows the distribution of modeled 10-year running sums of Lees Ferry gage flows in 2024, 2025, and 2026. The modeled 2024 flow is calculated using the observed deliveries from 2015 through 2022 and a modeled delivery volume in 2023. There is some variability in the 2023 volume, but it is common to all alternatives so it does not impact relative performance among alternatives.

The modeled 2025 volume drops the 2015 observed volume, and the modeled 2026 volume drops 2015 and 2016.

Each dot is the 10-year volume resulting from a single hydrologic trace. Dots may be plotted on top of one another. The top and bottom of each box captures the 25th to 75th percentile of the modeled elevations, the whiskers extend to the 5th and 95th percentiles, and the outliers are represented as dots beyond these lines.

The distributions of modeled 10-year running sums in **Figure 3-16** show that the median volumes decline over time for all alternatives and the interquartile and full ranges increase, with the ranges of the two action alternatives increasing more and toward the lower end compared to the No Action Alternative. In 2024, the median flow under the No Action Alternative is 84.6 maf and it decreases to 82.9 maf by 2026. In 2026, approximately 25 percent of modeled traces result in a flow volume less than 82.3 maf under the No Action Alternative. The minimum 10-year Lees Ferry flow volume resulting from the No Action Alternative is just above 75 maf in 2026.

Figure 3-16
Lees Ferry Gage 10-Year Running Total



The median modeled 10-year flows under the action alternatives are nearly identical throughout the period of performance, starting at 84 maf in 2024 and declining to 82.3 maf in 2025. In 2026, the medians under the action alternatives are 81.5 maf, meaning that more than half of modeled traces result in delivery volumes lower than 82.3 maf. The minimum delivery volume in 2026 under Action Alternative 1 is slightly above 72.6 maf, and the minimum for Action Alternative 2 is approximately

73.9 maf. The differences in modeled projections in the two action alternatives are greatest at the low end of the distributions in 2026, and they are a result of the different modeling assumptions for potential DROA contributions in Action Alternative 2 that can result in greater Lake Powell elevations and subsequent Glen Canyon Dam releases in some years. In 2026, approximately 10 percent of modeled deliveries under Action Alternative 1 and approximately 5 percent of Action Alternative 2 are below 75 maf.

Hoover Dam

Summary of Alternatives Comparison

The conclusions in this section are drawn from analyses of calendar year releases from Hoover Dam. Detailed comparisons of the alternatives follow in subsequent sections.

Under the No Action Alternative, the median modeled release from Hoover Dam is 8.5 maf in 2024, declining only slightly to 8.4 maf in 2026. The ranges around these medians for each year are relatively consistent, except in 2026 when the driest modeled traces result in Lake Mead reaching dead pool and Hoover Dam releases go as low as 5.3 maf.

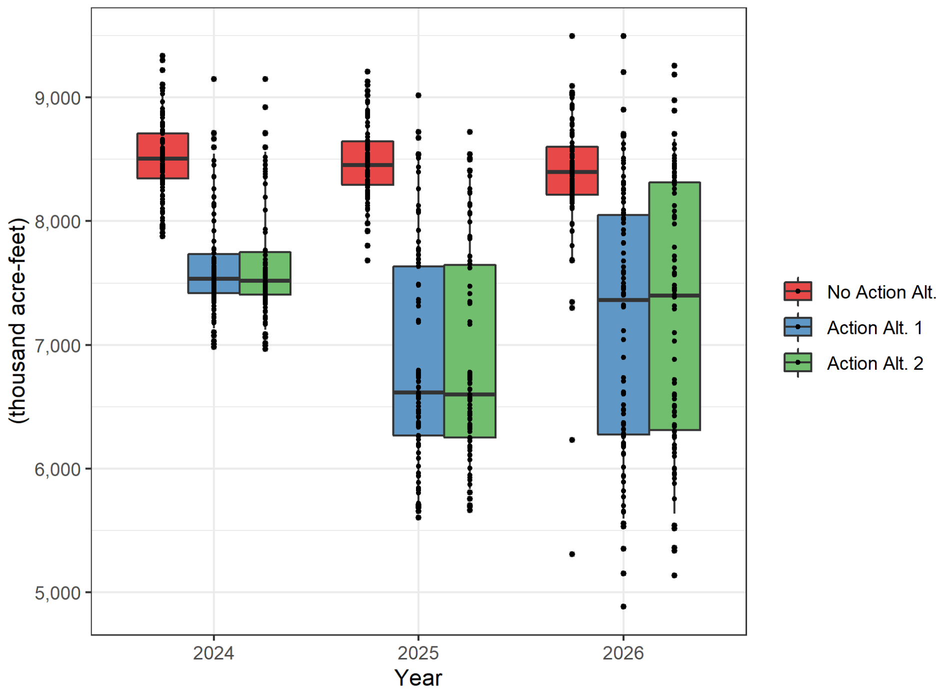
The median modeled annual Hoover Dam releases under the action alternatives are between 1 maf lower (2024) and 1.9 maf lower (2025) than the No Action Alternative. They also exhibit greater variability than the releases under the No Action Alternative: in 2026, the interquartile ranges for the action alternatives are more than 1.5 maf, while the interquartile range under the No Action Alternative is approximately 0.4 maf. The increased additional shortage volumes that are modeled in 2025 result in the lowest median releases of approximately 6.6 maf in 2025, but the shortages are effective at increasing Lake Mead elevations and they result in median modeled releases from Hoover Dam of approximately 7.4 maf in 2026.

Annual Release Volumes

Figure 3-17 shows the distributions of modeled calendar year release volumes from Hoover Dam in 2024, 2025, and 2026. Each dot is the annual volume produced by a single hydrologic trace. Dots may be plotted on top of one another. The top and bottom of each box captures the 25th to 75th percentile of the modeled elevations, the whiskers extend to the 5th and 95th percentiles, and the outliers represented as dots beyond these lines.

Figure 3-17 shows that under the No Action Alternative, the overall distribution of releases declines slightly from 2024 to 2026, where the median releases are 8.5 maf and 8.4 maf, respectively. The variability around the medians remains similar except in 2026, when approximately 5 percent of releases are below 7.5 maf and the minimum release is 5.3 maf. These extreme low releases occur in modeled traces when Lake Mead is at dead pool.

Figure 3-17
Hoover Dam Calendar Year Annual Release



Under the two action alternatives, **Figure 3-17** shows that the medians, ranges, and variability are very similar throughout the period of analysis. In 2024, 2025, and 2026, the medians of modeled Hoover Dam releases are approximately 7.5, 6.6, and 7.4 maf, respectively, and the ranges under both action alternatives more than doubles compared to 2024. The large decline in 2025 medians occurs because of the increases in additional shortage volumes applied below Lake Mead elevation 1,040 feet, and the subsequent increase in median modeled releases in 2026 occurs because the additional shortages act to increase the elevation in Lake Mead in many modeled traces. The minimum modeled release volumes occur in 2026 when Action Alternative 1 releases slightly less than 5 maf and Action Alternative 2 releases slightly more than 5 maf. The differences across the modeled projections of the two action alternatives are caused by their different assumptions about the distribution of additional shortage reductions and the different modeling assumptions for potential DROA contributions.

Davis Dam

Summary

The conclusions in this section are drawn from analyses of calendar year releases from Davis Dam. Detailed comparisons of the alternatives follow in subsequent sections.

Modeled annual releases from Davis Dam under the No Action Alternative are relatively consistent, with slight declines in the medians from 8.2 maf in 2024 to 8.1 maf in 2026. The variability around these medians is also consistent, except in 2026 when releases from Hoover Dam are limited in traces where Lake Mead reaches dead pool. The median annual releases from Davis Dam under the two action alternatives are lower and the ranges much wider than under the No Action Alternative. In 2024, 2025, and 2026, the medians are approximately 7.2, 6.3, and 7.0 maf, respectively. Increased additional shortage reduction volumes that are modeled in 2025 lead to increased 2026 elevations in Lake Mead and, therefore, increased releases from Hoover Dam relative to 2025.

Annual Release Volumes

Figure 3-18 shows the distributions of modeled calendar year release volumes from Davis Dam in 2024, 2025, and 2026. Each dot is the volume produced by a single hydrologic trace, and dots may be plotted on top of one another. The boxes capture the 25th to 75th percentile of the modeled elevations and the whiskers extend to the 5th and 95th percentiles, with outliers represented as dots beyond these lines.

Figure 3-18
Davis Dam Annual Release

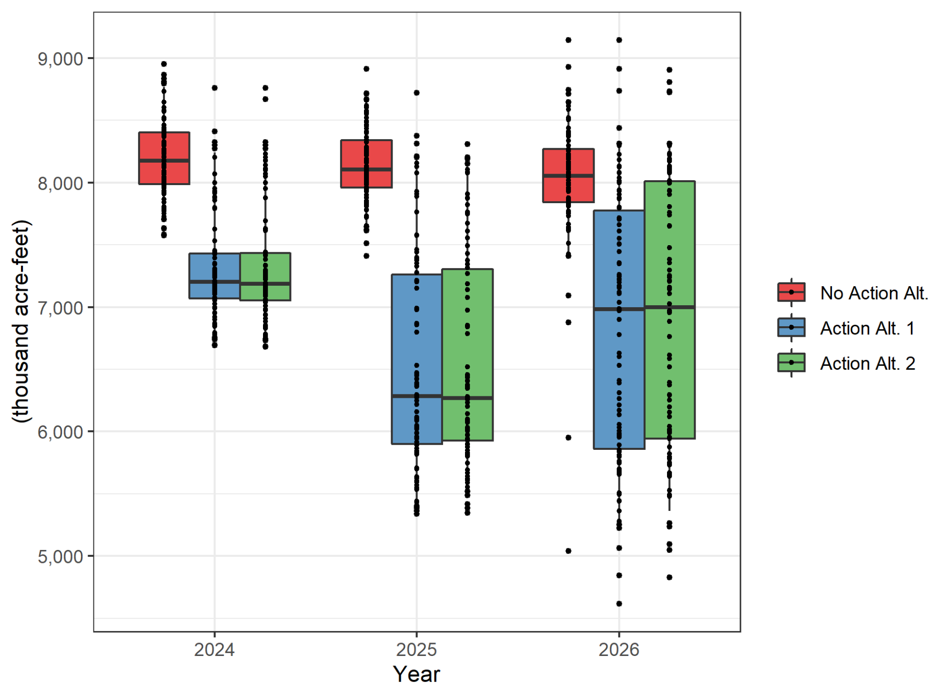


Figure 3-18 shows that, under all alternatives, the distributions of modeled annual releases from Davis Dam follow the same pattern as the releases from Hoover Dam because Hoover Dam releases are impounded in Lake Mohave and released from Davis Dam to generate hydropower. The median releases under the No Action Alternative are 8.2, 8.1, and 8.05 maf in 2024, 2025, and 2026, respectively, and the ranges stay relatively consistent except in 2026, when the driest modeled traces result in limited releases from Hoover Dam because Lake Mead has reached dead pool. The median releases from Davis Dam under the two action alternatives are approximately 7.2, 6.3, and 7.0 maf in 2024, 2025, and 2026, respectively. The ranges in 2025 and 2026 under the action alternatives are more than twice as wide as the ranges under the No Action Alternative. The minor differences in the modeled projections of the two action alternatives are caused by their different assumptions

about the distribution of additional shortage reductions and the different modeling assumptions for potential DROA contributions.

Parker Dam

Summary

The conclusions in this section are drawn from analyses of calendar year releases from Parker Dam. Detailed comparisons of the alternatives follow in subsequent sections.

Over the period of analysis, the No Action Alternative results in minimal variation in the median modeled annual release from Parker Dam of approximately 6.3 maf. There are also only minimal variations in the range of releases under the No Action Alternative, with the exception of 2026 when four of the modeled traces result in limited releases from Hoover Dam because Lake Mead is at dead pool. In 2026, the minimum Parker Dam release under the No Action Alternative is 3.3 maf.

The medians and ranges of modeled annual releases from Parker Dam are lower under the action alternatives compared to the No Action Alternative, but unlike in analyses of effects upstream, the different assumptions about the distribution of additional shortage reductions cause significant variation between the two alternatives. The median annual releases under Action Alternative 2 are 500,000 to 700,000 af lower than those of Action Alternative 1 every year, and ranges for both action alternatives are commensurate with the differences in medians. The minimum releases in 2026 (also the minimums for entire period of analysis) deviate from this, as under both action alternatives, the minimum modeled annual releases from Parker Dam are approximately 4.2 maf.

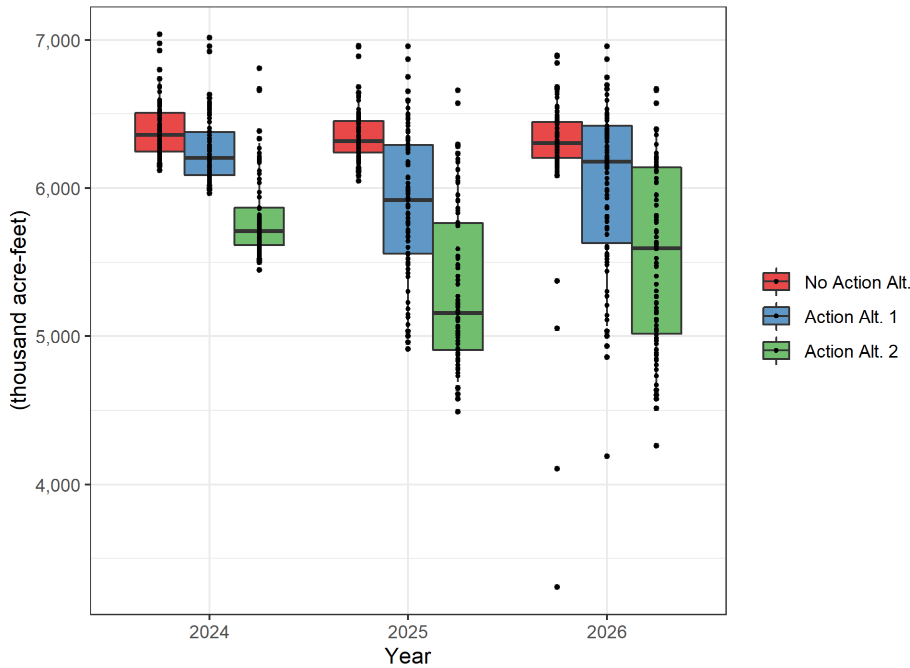
Annual Release Volumes

Figure 3-19 shows the distributions of modeled calendar year release volumes from Parker Dam in 2024, 2025, and 2026. Each dot is the volume produced by a single hydrologic trace, and dots may be plotted on top of one another. The boxes capture the 25th to 75th percentile of the modeled elevations and the whiskers extend to the 5th and 95th percentiles, with outliers represented as dots beyond these lines.

Figure 3-19 shows that under the No Action Alternative, modeled annual releases from Parker Dam do not vary significantly across years in either the medians, which are all approximately 6.3 maf or the ranges. The exceptions to these observations occur in 2026, when the modeled releases are as low as 3.3 maf because Lake Mead is at dead pool and releases from Hoover Dam are limited.

The medians and ranges of modeled annual releases from Parker Dam are lower under the two action alternatives, but unlike in analyses of upstream releases, the different assumptions about the distribution of additional shortage reductions cause significant differences. In 2024, 2025, and 2026, the median releases under Action Alternative 1 are 6.2, 5.9, and 6.2 maf, respectively. The median annual releases from Parker Dam under Action Alternative 2 are 500,000 to 700,000 af lower each year, at 5.7, 5.2, and 5.6 maf, respectively. The ranges for each year under each action alternative vary similarly to the medians, except for the 2026 minimum releases of approximately 4.2 maf for both alternatives (which are also the minimums for the period of analysis).

Figure 3-19
Parker Dam Annual Release



Cumulative Effects

Implementation of one of the Glen Canyon Dam/Smallmouth Bass flow options would not result in changes to annual reservoir releases from Glen Canyon Dam (Lake Powell) or Hoover Dam (Lake Mead). The operating tiers and corresponding volumes of annual Glen Canyon Dam releases established by this SEIS would determine sub-annual timing of Glen Canyon Dam releases (hourly, daily, monthly, and experimental), including potential flows associated with the flow options. Therefore, no additive cumulative effects would occur to reservoir releases due to proposed operational changes evaluated in the EA.

Issue 3: How would changes to operational activities affect river flows?

This section presents a comparison of river flows under the No Action Alternative, Action Alternative 1, and Action Alternative 2 in various metrics, including annual, monthly, and daily release volumes. Because in most cases the river flows in each reach are mainly made up of upstream reservoir releases, most discussion below will refer to figures in *Issue 2*.

Glen Canyon Dam to Lake Mead

Summary of Alternatives Comparison

As described in the 2007 FEIS, the river flows that occur between Glen Canyon Dam and Lake Mead result primarily from controlled releases from Glen Canyon Dam (Lake Powell). The gains from tributaries in this reach on average are less than 3 percent of the total flow, are concentrated over very short periods of time, and they would not be affected by the proposed alternatives. However, future annual and the monthly distribution of releases from Glen Canyon Dam may be affected by the proposed alternatives (see *Issue 2*).

With respect to annual flows, **Figure 3-14** shows modeled distributions of operating year releases from Glen Canyon Dam for the period of analysis. In general, both action alternatives result in nearly identical distributions of releases and they have slightly lower median release volumes than the No Action Alternative, but the releases resulting from dryer traces can be significantly lower. (See *Issue 2* for additional discussion.)

Distributions of modeled monthly flows between Glen Canyon Dam and Lake Mead for all alternatives are presented in **Figure 3-15**. Compared to the No Action Alternative, the two action alternatives have lower releases in October through March, with less variability, and higher and more variable releases compared to the No Action Alternative in April through September. This is a function of operations in the new Lower Elevation Release Tier, which is modeled to begin the operating year with a 6.0 maf release pattern with an optional upward April adjustment. (See *Issue 2* for additional discussion.)

Daily flows were not estimated for this SEIS. However, a table of estimates can be found in Section 4.3.3.1 of the 2007 FEIS. **Figure 3-15** shows how monthly releases from Glen Canyon Dam compare to an estimate of how daily minimum flows specified by LTEMP would sum to a monthly volume. With respect to beach habitat-building flows in the Grand Canyon, monthly flows are likely to have more effects on sediment. **Section 3.8** of this SEIS addresses the effects of high-flow experiments (HFEs) and monthly volume releases in the Grand Canyon. The timing of releases is also addressed in conjunction with other resources, such as sedimentation.

Hoover Dam to Davis Dam

Summary of Alternatives Comparison

As described in the 2007 FEIS, the river flows between Hoover Dam and Lake Mohave are comprised mainly of releases from Hoover Dam (Lake Mead) and tributary inflows. These tributary inflows, mostly from side washes, comprise less than 1 percent of the total annual flow in this reach. Future annual and monthly releases may be affected by the proposed alternatives. However, due to the presence of Lake Mohave immediately downstream, these potential changes in releases will only have an effect on hydropower generation.

Distributions of modeled annual releases from Hoover Dam are shown in **Figure 3-17**. In general, the action alternatives result in nearly identical distributions of releases, and their median annual releases from Hoover Dam are significantly lower than releases under the No Action Alternative. The action alternatives also exhibit significantly more variability than the No Action Alternative. The minimum annual releases under all alternatives occur in 2026, and they are 5.3, 4.9, and 5.1 maf for the No Action Alternative, Action Alternative 1, and Action Alternative 2, respectively. (See *Issue 2* for additional discussion.) With lower modeled annual releases from Hoover Dam in the action alternatives compared to the No Action Alternative, it is expected that monthly releases and river flows also would be lower.

Davis Dam to Parker Dam

Summary of Alternatives Comparison

River flows between Davis Dam and Parker Dam are mostly comprised of releases from Davis Dam and tributary inflow from the Bill Williams River. Releases from Davis Dam are the variable that would differ between alternatives so they are used for comparison. Distributions of modeled annual releases from Davis Dam are shown in **Figure 3-18**. In general, the action alternatives result in nearly identical distributions of releases and their median annual releases from Davis Dam are significantly lower than releases under the No Action Alternative. The action alternatives also exhibit significantly more variability than the No Action Alternative. The minimum annual releases under all alternatives occur in 2026, and they are 5.0, 4.6, and 4.8 maf for the No Action Alternative, Action Alternative 1, and Action Alternative 2, respectively. (See *Issue 2* for additional discussion.) With lower annual releases from Davis Dam in the action alternatives compared to the No Action Alternative, it is expected that monthly releases and river flows would also be lower.

With respect to annual flows near Lake Havasu National Wildlife Refuge (NWR), these river flows show the same general patterns that were observed in the distributions of modeled annual releases from Hoover Dam and Davis Dam since those dams are operated, except during flood control operations, to meet downstream demands. The differences in magnitudes between the releases from Hoover Dam, releases from Davis Dam, and flows near Havasu NWR are due to evaporation loss at Lake Mohave (which would be the same in all of the alternatives due to rule curve operations) and the relatively small diversions along this stretch of the river. (For more information about ecological impacts, see **Section 3.13** of this SEIS.)

Parker Dam to Cibola Gage and Cibola Gage to Imperial Dam

Summary of Alternatives Comparison

The river flows in this reach are essentially the releases from Parker Dam. **Figure 3-19** shows the distributions of modeled annual releases from Parker Dam for all alternatives. In general, the action alternatives result in lower median annual releases than the No Action Alternative and also significantly wider ranges in 2025 and 2026. The medians and ranges of the two action alternatives are significantly different from each other due to different assumptions about the distribution of additional shortage reductions, with modeled annual releases from Parker Dam under Action Alternative 2 being lower than those under Action Alternative 1. The minimum annual releases under all alternatives occur in 2026, and they are 3.3, 4.2, and 4.25 maf for the No Action Alternative, Action Alternative 1, and Action Alternative 2, respectively. (See *Issue 2* for additional discussion.)

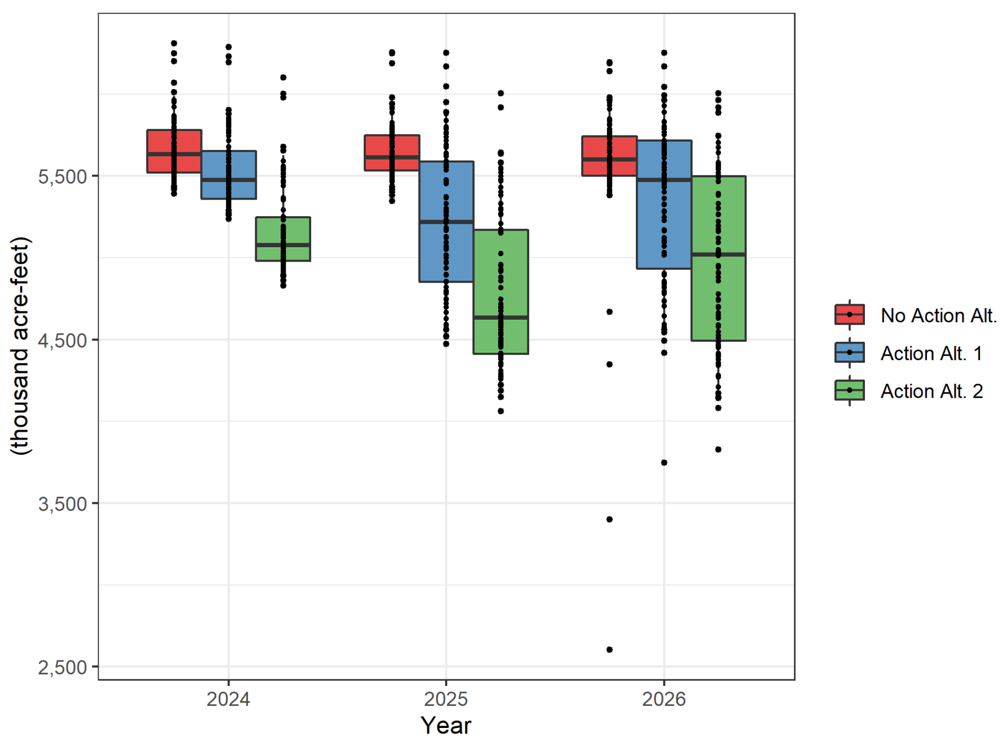
Two other points on the Colorado River are used to analyze flows in the reach between Parker Dam and Imperial Dam: flows near the Colorado River Indian Reservation (CRIR) and flows downstream of the Palo Verde Diversion Dam. The CRIR diversion is located at Headgate Rock Dam, approximately 14 miles downstream of Parker Dam. Flows in this reach of the river result primarily from releases at Parker Dam, and the annual flow values at this location generally reflect the releases from Parker Dam. Therefore, differences between the alternatives at this location can be assumed to be reflected in the comparison of releases from Parker Dam.

The flow of the Colorado River between Palo Verde Diversion Dam and Imperial Dam is normally the amount needed to meet both the consumptive use requirements in the US downstream of the Palo Verde Diversion Dam and deliveries to Mexico. The river location that was used to analyze the flows in the reach of the river between Palo Verde Diversion and Imperial Dam is located immediately downstream of the Palo Verde Diversion.

Figure 3-20 shows the distributions of modeled calendar year release volumes downstream of the Palo Verde Diversion Dam in 2024, 2025, and 2026. Each dot is the volume produced by a single hydrologic trace, and dots may be plotted on top of one another. The boxes capture the 25th to 75th percentile of the modeled elevations and the whiskers extend to the 5th and 95th percentiles, with outliers represented as dots beyond these lines.

In **Figure 3-20**, the distributions of modeled annual flow downstream of Palo Verde Diversion Dam under all alternatives follow the same pattern that was observed in the releases from Parker Dam in **Figure 3-19**: medians and variability in the No Action Alternative remain stable throughout the period of analysis, Action Alternative 1 has lower median flows and wider ranges than the No Action Alternative, and Action Alternative 2 has lower median flows than Action Alternative 1 due to different assumptions about the distribution of additional shortage reductions. As was discussed in previous analyses, the No Action Alternative has traces that modeled flow volumes far below the rest of the distribution because of the limitations in Hoover Dam releases when Lake Mead is at dead pool. The minimum annual flows under all alternatives occur in 2026, and they are 2.6, 3.75, and 3.8 maf for the No Action Alternative, Action Alternative 1, and Action Alternative 2, respectively.

Figure 3-20
Colorado River Annual Flow Downstream of Palo Verde Diversion Dam



Imperial Dam to NIB

Summary of Alternatives Comparison

As discussed in the 2007 FEIS, most of the water delivered to Mexico is diverted at Imperial Dam, conveyed via the All-American Canal, and then returned to the Colorado River through the Pilot Knob and Siphon Drop Powerplants and their respective wasteway channels, 2.1 miles and 7.6 miles upstream of the NIB, respectively. The proposed alternatives will not alter operation of these diversions and wasteways and, therefore, will not have an effect on this river reach.

NIB to SIB

Summary of Alternatives Comparison

As discussed in the 2007 FEIS, Mexico receives most of its Colorado River supply at the NIB and diverts it into the Reforma Canal at the Morelos Diversion Dam. Outflows from the Morelos Diversion Dam into the historical Colorado River floodplain area are normally limited, except during flood control events, or any potential future targeted environmental flows under Minute 323. No Lake Mead flood control releases have occurred since 2008 (after the implementation of the 2007 Interim Guidelines) and none are projected to occur in the next 4 years in the SEIS modeling. Therefore, neither the No Action Alternative nor either action alternative projects any flood control releases from 2023–2026. Additionally, deliveries to Mexico are outside the scope of this SEIS and, therefore, further analysis is not required.

Cumulative Effects

Implementation of one of the Glen Canyon Dam/Smallmouth Bass flow options EA would not result in changes to reservoir releases from Glen Canyon Dam (Lake Powell) or Hoover Dam (Lake Mead). The operating tiers established by this SEIS would inform the Glen Canyon Dam flow rates and volumes. Therefore, no additive cumulative effects would occur on flow rates within the various reaches of the Colorado River due to proposed operational changes evaluated in the EA.

Issue 4: How would operational activities affect groundwater?

Based on the modeling assumptions discussed previously, and considering the proposed alternatives, this section presents resulting differences associated with groundwater within specific reaches along the Colorado River for the No Action Alternative, Action Alternative 1, and Action Alternative 2. This qualitative analysis is informed by the assumptions, analyses, and findings of the 2007 FEIS. Further declines to groundwater levels as a result of potential reduced flows are assumed by Reclamation to be similar to those declines calculated in the 2007 FEIS.

Glen Canyon Dam to Lake Mead

Summary of Alternatives Comparison

The 2007 FEIS did not consider effects on groundwater elevations in the vicinity of Lake Powell; however, fluctuating reservoir elevations may be mirrored in groundwater elevations adjacent to the reservoir. As discussed in *Issue 1*, the No Action Alternative results in a lower monthly median reservoir elevation at Lake Powell and a larger number of model traces falling below critical elevations as compared to Action Alternative 1 and Action Alternative 2. Decreases in groundwater elevation adjacent to Lake Powell are anticipated to be larger under the No Action Alternative, as compared with the action alternatives.

As stated in the 2007 FEIS, the reach of the Colorado River downstream of the Glen Canyon Dam runs through the incised Grand Canyon where there is limited connection to groundwater. Due to these physical characteristics, there are assumed by Reclamation to be no differences between the No Action Alternative, Action Alternative 1, and Action Alternative 2. The alternatives are not anticipated to affect groundwater levels within this reach.

The 2007 FEIS did not consider effects on groundwater elevations in the vicinity of Lake Mead; however, fluctuating reservoir elevations may be mirrored in groundwater elevations adjacent to the reservoir. As discussed in *Issue 1*, the No Action Alternative exhibits declining median elevations through the analysis period and a large number of model traces falling below critical elevations as compared to Action Alternative 1 and Action Alternative 2, which generally decline through 2024 and then begin to recover in 2025 and 2026. Groundwater elevations adjacent to Lake Mead may fluctuate throughout the analysis period. At the end of 2026, decreases in groundwater elevation adjacent to Lake Mead are anticipated to be larger under the No Action Alternative, as compared with the action alternatives.

Hoover Dam to Davis Dam

Summary of Alternatives Comparison

As stated in the 2007 FEIS, this reach of the Colorado River runs through bedrock canyon that has limited connection to groundwater, or the reach is part of a groundwater basin that is dominated by Lake Mohave. There are assumed by Reclamation to be no differences between the alternatives and the alternatives are not anticipated to impact groundwater levels within this reach.

Davis Dam to Parker Dam

Summary of Alternatives Comparison

Due to the physical characteristics of the Davis Dam to Parker Dam reach of the Colorado River, groundwater levels are anticipated to decrease in the upper portion of the reach and remain static in the lower portion under all proposed alternatives. As discussed in *Issue 3*, river flows could decrease. Decreasing river flows and shallower river stages in this reach have historically resulted in decreased groundwater elevations. Decreases in the groundwater elevation in the upper portion of this reach are anticipated to be larger under the Action Alternatives 1 and 2, as compared with the No Action Alternative. This is because the Action Alternative 1 and Action Alternative 2 experiences lower flow rates through this portion of the Colorado River due to the shortage allocations.

Parker Dam to Cibola Gage and Cibola Gage to Imperial Dam

Summary of Alternatives Comparison

Due to the physical characteristics of the Parker Dam to Imperial Dam reach of the Colorado River, groundwater levels are anticipated to decrease under all proposed alternatives. As discussed in *Issue 3*, river flows could decrease. Decreasing river flows and shallower river stages in this reach have historically resulted in decreased groundwater elevations. Decreases in the groundwater elevation are anticipated to be larger under Action Alternative 1 and Action Alternative 2, as compared with the No Action Alternative. This is because Action Alternative 1 and Action Alternative 2 experience lower flow rates through this portion of the Colorado River due to the shortage allocations.

Imperial Dam to NIB

Summary of Alternatives Comparison

As stated in the 2007 FEIS, this reach of the Colorado River either runs through two small rockbound groundwater basins, or it is diverted to the All-American Canal. There are assumed by Reclamation to be no differences between the alternatives and the alternatives are not anticipated to impact groundwater levels within this reach.

NIB to SIB

Summary of Alternatives Comparison

As stated in the 2007 FEIS, this reach of the Colorado River runs through the large and deep river delta. The upstream portion is a gaining reach where groundwater contributes to surface flow in the river. The downstream portion is a losing reach where surface water from the river recharges the groundwater. While Action Alternative 1 and Action Alternative 2 alter the flow in the Lower Basin reaches differently than the No Action Alternative, impacts on groundwater levels are not anticipated within this reach across all alternatives.

Cumulative Effects

Implementation of one of the Glen Canyon Dam/Smallmouth Bass flow options would not result in changes to reservoir releases from Glen Canyon Dam (Lake Powell) or Hoover Dam (Lake Mead). The operating tiers established by this SEIS will inform the upcoming Glen Canyon Dam EA flow rates and volumes. Therefore, no additive cumulative effects would occur on groundwater levels within the various reaches of the Colorado River due to proposed operational changes evaluated in the EA.

3.7 Water Deliveries

3.7.1 Affected Environment

As described in the 2007 FEIS, entities in the seven Basin States and Mexico receive water from the Colorado River. The Law of the River governs these deliveries. Since issuance of the 2007 FEIS, deliveries to the Lower Basin states have been adjusted to meet the 2007 Interim Guidelines under certain conditions (Shortage Condition Years) and the Lower Basin DCP (Reclamation 2019b). The Upper Basin DCP also has been implemented since issuance of the 2007 FEIS with the goal of moving water within the Upper Basin to keep the pool elevation in Lake Powell above critical levels. Otherwise, deliveries to these entities are guided by the same body of documents described in the 2007 FEIS.

The Compact, described in the 2007 FEIS, ultimately apportioned water for consumptive use (7.5 maf each) between the Upper Basin and Lower Basin, with the division of the two basins at Lee Ferry, Arizona. The Upper and Lower Basins further apportion deliveries to individual states and entities within their respective basins. As discussed within this SEIS, the 2007 Interim Guidelines outline shortage guidelines that allow for the reduction of available water for consumptive use to the Lower Division States, below their apportioned 7.5 maf. Additionally, the 2007 Interim Guidelines modified and extended the 2001 Interim Surplus Guidelines (DOI 2001) from 2016 to 2026.

This section presents updated information on the Basin through 2022 to better describe evolving characteristics of water deliveries within the affected environment. This includes updated information regarding the apportionments to upper and Lower Division States, entitlements, depletion schedules for Lower Division States, and distribution of shortages for the Lower Division States.

Apportionments to the Upper Division States

As described in the 2007 FEIS, the Compact apportions 7.5 maf to the Upper Basin for consumptive use. Furthermore, flow at the Lee Ferry Compact Point cannot be depleted below 75 maf for any consecutive 10-year period. The annual apportionment is a percentage of the total available for consumptive use each year. The available amount within the Upper Basin is the remaining volume after Arizona's 50,000 af apportionment of Upper Basin water. Further details on the Upper Division States' apportionments and depletion schedules can be found in the 2007 FEIS. The state's apportionments are listed in **Table 3-4**. The 2007 Interim Guidelines do not affect the apportionments of the Upper Division States.

Table 3-4
Upper Division States Apportionment

State	Annual Apportionment (Percent)
Colorado	51.75
New Mexico	11.25
Utah	23.00
Wyoming	14.00

Source: Reclamation 2007

Apportionments to the Lower Division States

As stated in the 2007 FEIS, the BCPA establishes the apportionments of water to the Lower Division States. Details on these states' apportionments can be found in the 2007 FEIS. The states' apportionments are listed in **Table 3-5**.

Table 3-5
Lower Division States Apportionments

State	Annual Apportionment (maf)
Arizona	2.8
California	4.4
Nevada	0.3
Total	**7.5**

Source: Reclamation 2007

The 2007 Interim Guidelines do not affect the apportionments of water to the Lower Division States. Therefore, further discussion of these schedules is not warranted; additional detail can be found in the 2007 FEIS.

Water Delivery Entitlements to Entities in the Lower Division States

As stated in the 2007 FEIS, the Lower Basin states' apportioned water is further allocated through entitlements, in accordance with the BCPA and Consolidated Decree.[8] Approximately 10,000 af of Arizona's lower Colorado River water apportionment has not been allocated. The 2007 Interim Guidelines do not affect the entitlements in the Lower Division States; additional details on these entitlements can be found in the 2007 FEIS.

Additionally, the 2007 Interim Guidelines created ICS. This allows Lower Basin contractors to store unused portions of their entitlements in Lake Mead. Special conservation programs must be used to allocate water through this storage credit. ICS creation and deliveries are subject to constraints as defined in the 2007 ROD and 2019 DCPs (specifically Exhibit 1).

Lower Division States Water Supply Determination

As discussed in the 2007 FEIS, the Secretary annually determines the water supply condition for the Lower Division States as a normal condition, surplus condition, or shortage condition, depending on the amount of mainstream water available to satisfy consumptive use in the Lower Division States. The 2007 Interim Guidelines provide specific guidance used to make annual water supply determinations. This guidance is based on the elevations of Lake Powell and Lake Mead. The guidance identifies thresholds under which the Secretary would reduce the total amount of water available—below 7.5 maf—for consumptive use from Lake Mead to the Lower Division States. The 2007 Interim Guidelines also provide a coordinated approach to reservoir management between Lake Powell and Lake Mead.

Starting in 2008, Reclamation has operated Lake Powell for each operating year based on certain release tiers, which is consistent with Section 6.C.1 of the 2007 Interim Guidelines. Similarly, Reclamation has set the condition governing operation of Lake Mead for each calendar year consistent with Section 2.D.1 of the 2007 Interim Guidelines and in accordance with Article III(3)(c) of the Operating Criteria and Article II(B)(3) of the Consolidated Decree of the Supreme Court of the US in *Arizona v. California*, 547 US 150 (2006). Starting in 2019, the Lower Basin DCP (Reclamation 2019b) also governs the operation of Lake Mead.

Each year's AOP for Colorado River reservoirs reports on both the past operations of the Colorado River reservoirs for the completed year and the projected operations and releases from these reservoirs for the current (that is, upcoming) year. Each AOP incorporates rules, guidelines, and decisions. The AOP reports how Reclamation will implement these decisions in response to changing water supply conditions as conditions become known during the upcoming year. The water supply condition for each year since 2008 has been normal/ICS surplus in accordance with the 2007 Interim Guidelines, with the exception of 2022 and 2023. Inflow projections and reservoir elevations led to a water supply determination for 2022 as a Shortage Condition Year, and water deliveries to the Lower Basin states were reduced to 7.167 maf. The water supply determination for 2023 was a Shortage Condition Year, and water deliveries will be limited to 7.083 maf and further adjusted for required DCP contributions.

---

[8] As discussed in the 2007 FEIS, the Consolidated Decree was entered by the US Supreme Court in the case of *Arizona v. California*, 547 US 150 (2006).

As discussed in the 7D Review Final Report released in December 2020 (Reclamation 2020a), the Interim Guidelines provide operational criteria for the full range of potential reservoir elevations that may occur based on modeling conducted for the 2007 FEIS. The guidelines were intended to govern operations through 2026. However, the continuing drought within the Basin has increased the probability that the water supply system will be unable to make required releases. In addition, reservoir levels have continued to fall to the point that critical infrastructure and hydropower operations may be negatively impacted.

This fact motivated the completion of the DCPs when, in 2018, combined storage was at the lowest point since Lake Powell filled (41 percent full), and the Basin was experiencing the second-driest year since the beginning of the drought (Reclamation 2020a). Even with the DCPs in place, the risk of continued drought and reservoir elevations declining below those considered likely in the 2007 FEIS requires the consideration of updates to the 2007 Interim Guidelines to protect the reservoir elevations of Lake Powell and Lake Mead through 2026. The proposed updates being considered (Action Alternative 1 and Action Alternative 2), and their effect on water deliveries to Lower Division States, are presented in **Section 3.7.2**, Environmental Consequences, of this SEIS.

Depletion Schedules for Lower Division States (Normal and Surplus)

Historical consumptive use for the Lower Basin from 2008 to 2021 is shown in **Table 3-6**. 2008 was selected since that is when the 2007 Interim Guidelines were implemented. At the time of this report, data was not available after 2021. Total annual diversions to the Lower Basin have declined on average from 2008 to 2020.

Table 3-6
Lower Basin Annual Historical Consumptive Use by State

Calendar Year	Arizona (af)	California (af)	Nevada (af)	Lower Basin Total (af)
2008	2,752,497	4,498,810	269,654	7,520,961
2009	2,831,711	4,358,074	248,613	7,438,398
2010	2,780,367	4,356,839	241,437	7,378,643
2011	2,781,108	4,312,661	222,847	7,316,616
2012	2,789,667	4,416,718	237,161	7,443,546
2013	2,778,867	4,475,789	223,563	7,478,219
2014	2,774,661	4,649,734	224,616	7,649,011
2015	2,604,732	4,620,756	222,729	7,448,217
2016	2,612,833	4,381,101	238,326	7,232,260
2017	2,509,503	4,026,515	243,425	6,779,443
2018	2,632,260	4,265,525	244,103	7,141,888
2019	2,491,707	3,840,686	233,996	6,566,389
2020	2,470,776	4,059,911	255,568	6,786,255
2021	2,425,736	4,404,727	242,168	7,072,631

Source: Reclamation 2022d

Projected depletion schedules have been modified since the 2007 FEIS. **Appendix C**, CRMMS Model Documentation, outlines the current depletion schedules used in normal and surplus[9] conditions. For the first year of the model run, projected depletion schedules use water orders that reflect shortage conditions, DCP contributions, and other signed system conservation agreements. For the remaining years in the model run, projected depletion schedules reflect "normal" schedules, and represent near-term historical trends in water use.

Mexico's Allotment

The specifics of the allotment are detailed in the 2007 FEIS. The 2007 Interim Guidelines and this SEIS do not affect Mexico's allotment. The amount of Colorado River water scheduled for delivery to Mexico during each calendar year has been set in accordance with the 1944 Water Treaty and IBWC Minute 323. Since 2019, this volume was further adjusted for water savings contributions, as required under Minute 323, and since 2021 for reductions under low elevation reservoir conditions. In accordance with the provisions of Minute 323,[10] Mexico may create water for or take delivery of water from Mexico's Water Reserve. The provisions also allow Mexico's Water Reserve to be converted into Mexico's Recoverable Water Savings, which offset savings contributions when Lake Mead has low reservoir elevations for recovery at a later date.

Distribution of Shortages to and within the Lower Division States

The 2007 FEIS describes the distribution of shortages within each state in accordance with established priority systems and agreements. This section provides supplemental information that impacts the distribution of shortages since issuance of the 2007 FEIS.

In the 2007 FEIS, the maximum volume of domestic shortages analyzed were 2.083 maf. As such, the total shortages in 2024, as modeled in this SEIS, are limited to 2.083 maf, the maximum volume analyzed in the 2007 FEIS. Working within this range of previously analyzed impacts will facilitate completing this SEIS process in the time available in advance of the 2024 operating year. While shortages greater than 2.083 maf are modeled in 2025 and 2026 as part of this SEIS, analyzing shortages greater than 2.083 maf would require additional detailed analysis and stakeholder coordination. Working within this range of previously analyzed impacts will facilitate completing this SEIS process in the time available in advance of the 2024 operating year. Delaying operational decisions to perform additional analyses would not meet the express purpose and need for this action.

The 2007 Interim Guidelines specified shortages for Arizona and Nevada based on the projected January 1 elevation of Lake Mead. The 2019 DCPs included additional contributions from Arizona, Nevada, and California at specified Lake Mead elevations. The breakdown of these volumes is described in Exhibit 1 to the Lower Basin DCP Agreement. **Table 3-7** below presents this breakdown.

---

[9] While surplus schedules exist in CRMMS, no surplus conditions are projected through 2026 in the No Action Alternative or the action alternatives.

[10] For implementing additional details see: *Joint Report of the Principal Engineers with the Implementing Details of the BWSCP in the Colorado River Basin dated July 11, 2019* and *Joint Report of the Principal Engineers with the Operational Provisions Applicable to Water for the Environment Stipulated in Minute 323 dated December 16, 2021.*

Table 3-7
Lower Division States' Total Shortages from the 2007 Interim Guidelines and Contributions from the 2019 DCPs

Projected January 1 Lake Mead Elevation (feet)	2007 Interim Guidelines Shortages		DCP Contributions			Combined Volumes (2007 Interim Guidelines Shortages & DCP Contributions)			
	Arizona	Nevada	Arizona	Nevada	California	Arizona	Nevada	California	Lower Division States Total
	(1,000 acre-feet)								
At or below 1,090 and above 1,075	0	0	192	8	0	192	8	0	200
At or below 1,075 and at or above 1,050	320	13	192	8	0	512	21	0	533
Below 1,050 and above 1,045	400	17	192	8	0	592	25	0	617
At or below 1,045 and above 1,040	400	17	240	10	200	640	27	200	867
At or below 1,040 and above 1,035	400	17	240	10	250	640	27	250	917
At or below 1,035 and above 1,030	400	17	240	10	300	640	27	300	967
At or below 1,030 and at or above 1,025	400	17	240	10	350	640	27	350	1,017
Below 1,025	480	20	240	10	350	720	30	350	1,100

Source: Reclamation 2019b

Distribution of Shortages within Arizona

As described in the 2007 FEIS, Arizona's 2.8-maf apportionment is further distributed through entitlements. A priority system was established for the delivery of mainstream Colorado River water. The following table (**Table 3-8**) from the 2007 FEIS outlines Arizona's priority system.

As outlined above, the 2007 Interim Guidelines and the 2019 DCPs define shortages and contributions from Arizona, which depend on the elevation of Lake Mead. The combined shortage and contribution volumes for Arizona range from 192,000 af to 720,000 af.

Table 3-8
Arizona's Priority System for Mainstream Colorado River Water

Priority	Rights to Be Satisfied
First	Present perfected rights (PPRs) established prior to June 25, 1929
Second[1]	Federal reservations and perfected rights established or effective prior to September 30, 1968
Third[1]	Entitlements pursuant to contracts executed on or before September 30, 1968

Priority	Rights to Be Satisfied
Fourth	(1) Entitlements pursuant to contracts, Secretarial reservations, and other arrangements between the US and water users established subsequent to September 30, 1968 (2) Contract for CAP
Fifth	Any unused Arizona entitlement
Sixth	Entitlements to surplus water

Source: Reclamation 2007

[1] The Arizona second and third priorities are coequal in their priority.

Distribution of Shortages within California

As described in the 2007 FEIS, California's 4.4-maf apportionment is further distributed through a priority system, established by Secretarial regulations incorporating provisions of the California Seven-Party Agreement of 1931. **Table 3-9** below from the 2007 FEIS outlines the priority system.

Table 3-9
California's Seven-Party Agreement for Mainstream Colorado River Water

Priority	Rights to Be Satisfied
First	Palo Verde Irrigation District for beneficial use upon 104,500 acres
Second	Reclamation's Yuma Project for beneficial use on up to 25,000 acres
Third[1,2]	(a) Imperial Irrigation District (IID) and Coachella Valley Water District (b) Palo Verde Irrigation District for use on 16,000 acres on the Lower Palo Verde Mesa
Fourth[3]	MWD and/or the City of Los Angeles and/or others on the coastal plain of Southern California for 550,000 acre-feet per year (afy)
Fifth	(a) MWD and/or the City of Los Angeles and/or others on the coastal plain of Southern California for 550,000 afy (b) City and/or County of San Diego for 112,000 afy
Sixth[4]	(a) IID and Coachella Valley Water District (b) Palo Verde Irrigation District for use on Lower Palo Verde Mesa
Seventh	All remaining water available within California for agricultural use

Source: Reclamation 2007

[1] The total beneficial use of priorities 1, 2, and 3 shall not exceed 3,850,000 afy.

[2] Article 4.7 of the Quantification Settlement Agreement (QSA) and the Agreement For Acquisition Of Conserved Water by and between IID and Coachella Valley Water District, dated October 10, 2003, contain provisions for shortage sharing between these two agencies.

[3] The sum of priorities 1 through 4 is 4,400,000 afy.

[4] The sum of priority 6 is 300,000 thousand afy.

As outlined above, the 2019 DCPs defines contributions from California, which depend on the elevation of Lake Mead. The contribution volumes for California range from 0 af to 350,000 af.

Distribution of Shortages within Nevada

As described in the 2007 FEIS, Nevada's 0.3-maf apportionment is further distributed through a priority system, established in 1992 when Reclamation contracted with SNWA for delivery of the balance of Nevada's apportionment. **Table 3-10**, updated from the 2007 FEIS, outlines the priority system.

Table 3-10
Nevada's Priority System for Mainstream Colorado River Water

Priority	Rights to Be Satisfied
First	Fort Mojave Indian Reservation (12,534 afy) LMNRA (Diversion = 500 afy or Consumptive Use = 300 afy)
Second	LMNRA (1,500 afy, estimated)
Third	Boulder City (5,876 afy)
Fourth	City of Henderson (15,878 afy) Basic Management, Inc. (8,608 afy) SNWA (from Basic Water Company) (14,950 afy)
Fifth	Lakeview Company (0 afy) Pacific Coast Building Products (PABCO) (928 afy)
Sixth	Las Vegas Valley Water District (15,407 afy)
Seventh	US Air Force (delivery from SNWA; 4,000 afy), Boy Scouts (annexed by SNWA; 10 afy), Reclamation (300 afy), and Nevada Department of Wildlife (formerly Nevada Department of Fish and Game; 25 afy)
Eighth	Robert B. Griffith Project (308,000 afy) and Big Bend (10,000 afy) SNWA (balance of state apportionment, unused and surplus)

Source: Reclamation 2007

3.7.2 Environmental Consequences

Methodology

This section compares water deliveries from the Colorado River mainstream under the No Action Alternative (baseline condition) and the action alternatives. CRMMS, as described in **Section 3.3**, was used to analyze water deliveries across these alternatives. Modeling details for each alternative are described in **Section 3.3.8** and **Appendix C**, CRMMS Model Documentation.

Additionally, as described in **Section 3.3**, Shortage Allocation Models were used in addition to CRMMS to analyze the potential impacts of each alternative on individual water users within each Lower Division State. The Shortage Allocation Models were used to estimate delivery of water to Colorado River water users within the Lower Division States under varying levels of shortage for each alternative. Modeling assumptions for the Shortage Allocation Models are summarized in **Section 3.3.8** and detailed in **Appendix D**, Shortage Allocation Model Documentation, which presents shortage impacts on entitlement holders. A list of each Lower Division State's Colorado River water-entitlement holders, listed by priority, is available at: https://www.usbr.gov/lc/region/g4000/contracts/entitlements.html.

The new actions evaluated as part of the SEIS will not impact Upper Division States; therefore, further analysis of the Upper Division States is not necessary and not included within this section.

Assumptions

(Please refer to **Section 3.3.8**, **Appendix C**, and **Appendix D** for a discussion pertaining to modeling assumptions.)

All calculated statistics are reflective of the hydrology scenarios and other assumptions used in modeling and they are not intended to suggest actual probabilities of any events occurring. However, it is meaningful to compare statistics across alternatives to differentiate performance.

Impact Indicators

This section will discuss impacts on the Lower Division States' water supply determination, total water deliveries to Lower Division States, deliveries to Mexico, and the distribution of shortages to and within the Lower Division States. To measure the impact of water deliveries, the following indicators are being used:

- frequency and magnitude of shortages
- distribution of shortages and depletions among and within the Lower Division States

Issue 1: How would changes to operational activities affect apportionments to the Upper Division States?

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

Issue 2: How would changes to operational activities affect apportionments and water entitlements to and within the Lower Division States?

The proposed alternatives will not affect state apportionments or entitlements of water users within the Lower Division States. Therefore, no impact analysis is warranted.

Issue 3: How would changes to operational activities affect Lower Division States' water supply determinations?

Summary of Alternatives

As discussed in **Chapter 2** and **Appendix C**, CRMMS Model Documentation, shortage and DCP contribution determinations for all alternatives were determined in response to Lake Mead elevations, outlined in **Table 3-11**, **Table 3-12**, and **Table 3-13**. As shown in **Figure 3-21**, all modeled traces, apart from one trace of the wettest hydrology scenario in 2026, experience December Lake Mead starting elevations below the threshold for shortages or DCP contributions (1,090 feet).

Table 3-11
Lower Division States' Shortages and DCP Contributions, No Action Alternative*
(Volumes in 1,000 af)

Lake Mead Elevation (feet)	No Action Alternative		
	2007 ROD Shortage	2019 DCP Contributions	Total Shortages and Contributions
1,090 – >1,075	0	200	200
1,075 – 1,050	333	200	533
<1,050 – >1,045	417	200	617
1,045 – >1,040	417	450	867
1,040 – >1,035	417	500	917
1,035 – >1,030	417	550	967
1,030 – 1,025	417	600	1017
<1,025 – 1,000	500	600	1100
<1,000 – 975	500	600	1100
<975 – 950	500	600	1100
< 950	500	600	1100

* This table only shows combined Lower Division State shortage volumes and DCP contributions. In addition to the volumes shown in this table, the analysis for each alternative includes water delivery reductions to Mexico under low elevation reservoir conditions and Mexico's savings that contribute to the BWSCP in accordance with Minute 323 to the 1944 Water Treaty.

Table 3-12
Lower Division States' Shortages and DCP Contributions, Action Alternatives 1 and 2 (2024)*
(Volumes in 1,000 af)

Lake Mead Elevation (feet)	No Action Alternative			Action Alternatives 1 and 2 (2024)	
	2007 ROD Shortage	2019 DCP Contributions	No Action Total	2024 Additional Shortage	2024 Total Shortages + Contributions
1,090 – >1,075	0	200	200	200	**400**
1,075 – 1,050	333	200	533	533	**1,066**
<1,050 – >1,045	417	200	617	617	**1,234**
1,045 – >1,040	417	450	867	867	**1,734**
1,040 – >1,035	417	500	917	1,166	**2,083**
1,035 – >1,030	417	550	967	1,116	**2,083**
1,030 – 1,025	417	600	1,017	1,066	**2,083**
<1,025 – 1,000	500	600	1,100	983	**2,083**
<1,000 - 975	500	600	1,100	983	**2,083**
<975 - 950	500	600	1100	983	**2083**
< 950	500	600	1100	983	**2083**

* This table only shows combined Lower Division State shortage volumes and DCP contributions. In addition to the volumes shown in this table, the analysis for each alternative includes water delivery reductions to Mexico under low elevation reservoir conditions and Mexico's savings that contribute to the BWSCP in accordance with Minute 323 to the 1944 Water Treaty.

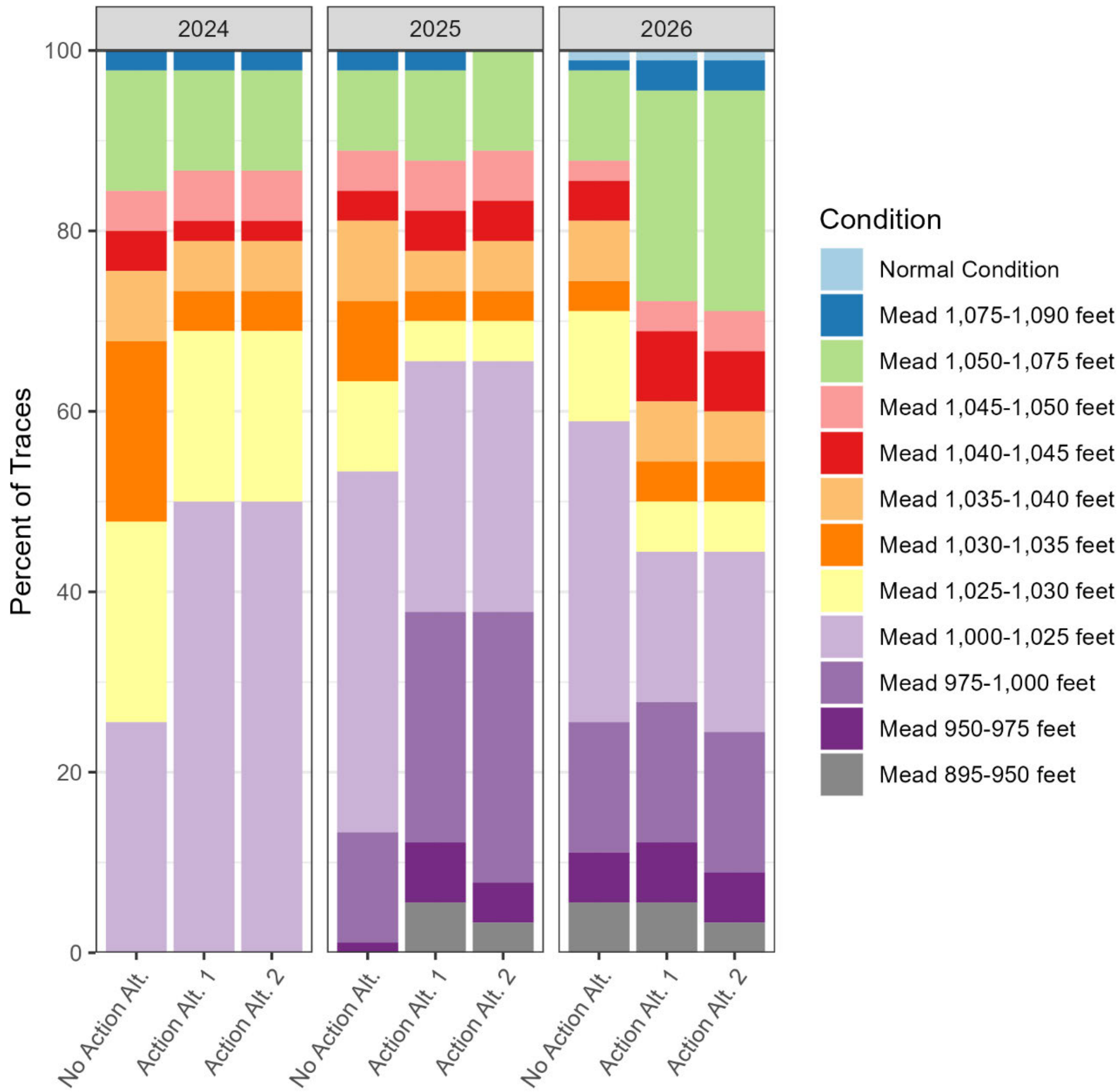
Table 3-13
Lower Division States' Shortages and DCP Contributions, Action Alternatives 1 and 2 (2025-2026)* (Volumes in 1,000 af)

Lake Mead Elevation (feet)	No Action Alternative			Additional Shortages under Action Alternatives 1 and 2 (2025–2026)	
	2007 ROD Shortage	2019 DCP Contributions	No Action Total	2025-2026 Additional Shortage**	2025-2026 Total Shortages + Contributions
1,090 – >1,075	0	200	200	200	**400**
1,075 – 1,050	333	200	533	533	**1,066**
<1,050 – >1,045	417	200	617	617	**1,234**
1,045 – >1,040	417	450	867	867	**1,734**
1,040 – >1,035	417	500	917	1,166	**2,083**
1,035 – >1,030	417	550	967	1,283	**2,250**
1,030 – 1,025	417	600	1,017	1,483	**2,500**
<1,025 – 1,000	500	600	1,100	1,900	**3,000**
<1,000 - 975	500	600	1,100	2,233	**3,333**
<975 - 950	500	600	1,100	2,567	**3,667**
< 950	500	600	1,100	2,900	**4,000**

* This table only shows combined Lower Division State shortage volumes and DCP contributions. In addition to the volumes shown in this table, the analysis for each alternative includes water delivery reductions to Mexico under low elevation reservoir conditions and Mexico's savings that contribute to the BWSCP in accordance with Minute 323 to the 1944 Water Treaty.

The scope of this NEPA analysis, including potential actions in 2025-2026, is discussed further in **Sections 1.2 and **1.5**.

Figure 3-21
Percent of Traces with Lower Division Shortage and DCP Tiers*

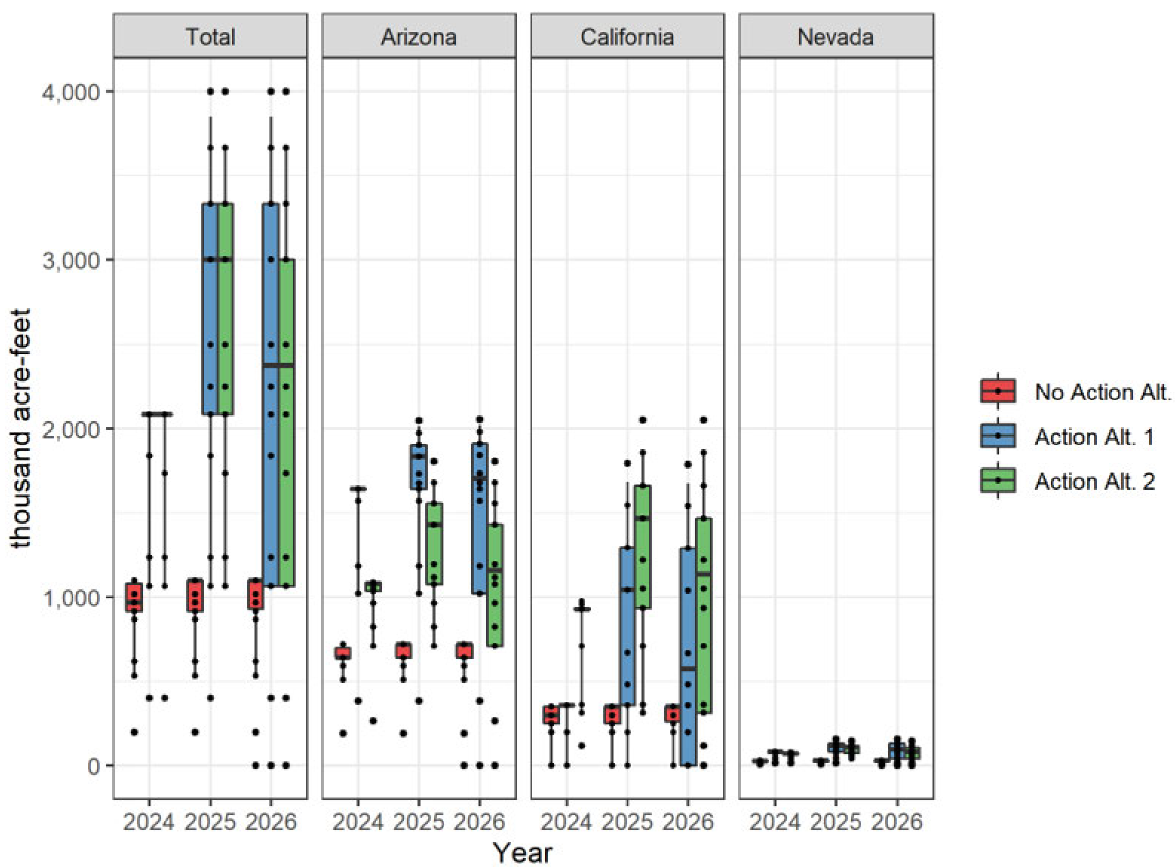


*Tiers for the No Action Alternative are based on effective pool elevation, while elevations for the action alternatives are based on physical elevation because the action alternatives model removing operational neutrality.

Under the No Action Alternative, combined shortages and DCP contributions for the Lower Division States are less than the action alternatives (the action alternatives increase shortages when Lake Mead is below elevation 1,090 feet), as shown in **Figure 3-22**. Total shortages and DCP contributions tend to increase over time under the No Action Alternative as reservoir elevations decrease; however, both action alternatives show total shortage and DCP contributions increasing through 2025 and then decreasing in 2026. This is because the larger modeled shortage volumes in 2025 and 2026 start to stabilize and increase Lake Mead elevations by 2026.

Figure 3-22 shows the distributions of Lower Division Shortages and DCP contributions for each state in 2024, 2025, and 2026. Each dot is the shortage volume produced by a single hydrologic trace, and dots may be plotted on top of one another. The boxes capture the 25th to 75th percentile of the modeled elevations and the whiskers extend to the 5th and 95th percentiles, with outliers represented as dots beyond these lines.

Figure 3-22
Distribution of Lower Division Shortages and DCP Contributions



Both action alternatives result in the same shortage tiers for the Lower Division States in 2024 and similar tiers in 2025 and 2026, as shown in **Figure 3-21**; however, the distribution of shortages among Lower Division States and water users changes according to the action alternative. When comparing the action alternatives, the two alternatives result in nearly the same total Lower Basin shortage; however, Action Alternative 1 results in greater combined total shortages and DCP contributions for Arizona and Nevada and reduced combined shortages and DCP contributions to California relative to Action Alternative 2. Equivalently, Action Alternative 2 results in greater combined total shortages and DCP contributions for California, thereby reducing combined shortages and DCP contributions for Arizona and Nevada relative to Action Alternative 1.

No Action Alternative

Figure 3-8 in **Section 3.6.2** shows the projected end-of-month pool elevations for Lake Mead from 2024 through 2026 for each alternative. The median pool elevation for the No Action Alternative begins below 1,025 feet under current policies. Under this alternative, the elevations of Lake Mead fluctuate, but they generally decline with an ending median elevation of 1,010 feet and minimum elevation reaching dead pool at 895 feet. The median elevation stays below 1,025 feet for the duration of the analysis period.

Combined specified shortage volumes and DCP contributions for the combined Lower Division States can be found in **Table 3-12** and **Table 3-13.** Combined specified shortage volumes and DCP contributions broken down by Lower Division State can be found in **Table 2-4** in **Section 2.7.1** for calendar year 2024 and **Table 3-1** for calendar years 2025-2026. The distribution of total modeled combined shortage volumes and DCP contributions throughout this analysis period is shown in **Figure 3-22**. For calendar years 2024-2026, Arizona experiences maximum modeled combined annual shortage volumes and DCP contributions of 720,000 af, California experiences 350,000 af in annual DCP contributions, and Nevada experiences 30,000 af in combined shortage volumes and DCP contributions. The maximum total specified and modeled Lower Division State combined shortage volumes and DCP contributions for calendar years 2024-2026 for the No Action Alternative is 1.100 maf.

Action Alternative 1

Action Alternative 1 includes reduced releases from Glen Canyon Dam, the use of physical elevations for tier determinations, and additional shortage volumes when Lake Mead is below 1,090 feet based exclusively on the concept of priority. Modeling assumptions for Action Alternative 1 are stated in **Section 3.3.8** and described in detail in **Appendix C**, CRMMS Model Documentation.

The median pool elevation for this alternative begins below 1,025 feet under current policies as shown in **Figure 3-8** in **Section 3.6.2**. Under Action Alternative 1, the median elevation of Lake Mead continues to generally decline through the end of 2024. From 2025 through 2026, the median elevation generally increases, reaching a median value of 1,039 feet in 2026. The range of all modeled traces shows a maximum monthly elevation in Lake Mead of 1,141 feet and a minimum of 895 feet, reaching dead pool.

Combined specified shortage volumes and DCP contributions for the combined Lower Division States can be found in **Table 3-12** and **Table 3-13.** Combined specified shortage volumes and DCP contributions broken down by Lower Division State can be found in **Table 2-4** in **Section 2.7.1** for calendar year 2024 and **Table 3-1** for calendar years 2025-2026. The distribution of total modeled combined shortage volumes and DCP contributions throughout this analysis period is shown in **Figure 3-22**. In calendar years 2024–2026, Arizona would experience maximum modeled annual shortage volumes and DCP contributions of 1.642 maf, 2.045 maf, and 2.053 maf, respectively. In 2024, California would experience a maximum of 357,000 af in annual DCP contributions, and in 2025–2026 it would experience combined annual DCP contributions and shortage volumes of 1.795 maf and 1.787 maf, respectively. In 2024, Nevada would experience a maximum of 83,000 af, and in both 2025 and 2026 it would experience a maximum of 160,000 af in combined shortage volumes and DCP contributions. The maximum total specified and total modeled Lower Division State combined shortage volumes and DCP contributions for calendar year 2024 for Action Alternative 1 is 2.083 maf and it does not include the full DCP contributions required of California. In 2025 and 2026, the total potential Lower Division State combined shortage volumes and DCP contributions for Action Alternative 1 is 4.000 maf a year.

Action Alternative 2

Action Alternative 2 includes reduced releases from Glen Canyon Dam; the use of physical elevations for tier determinations; additional shortage volumes when Lake Mead is below 1,090 feet that are distributed in the same percentage across all Lower Basin water users; and the potential for additional inflow to Lake Powell based on potential DROA contribution modeling assumptions. Modeling assumptions for Action Alternative 2 are stated in **Section 3.3.8** and described in detail in **Appendix C**.

Total shortage volumes and DCP contributions for the Lower Division States remain the same as under Action Alternative 1; however, the distribution of shortages among the Lower Division States changes. Under Action Alternative 2, the additional shortages are distributed at the same percentage across all Lower Basin water users, rather than based on priority. The range of total shortages and DCP contributions is nearly identical to those under Action Alternative 1. The only differences are due to small changes in Lake Mead's elevations that are related to how the assumptions for potential DROA contributions included in Action Alternative 2 affect Lake Powell's release. The distribution of total modeled combined shortage volumes and DCP contributions throughout this analysis period is shown in **Figure 3-22**.

In calendar year 2024, Arizona would experience maximum modeled annual combined shortage volumes and DCP contributions of 1,087,000 af, and in both 2025 and 2026, would experience combined annual DCP contributions and shortage volumes of 1.803 maf. In 2024, California would experience a maximum of 975,000 af in annual DCP contributions, and in both 2025 and 2026, would experience combined annual DCP contributions and shortage volumes of 2.051 maf. In 2024, Nevada would experience a maximum of 74,000 af, and in both 2025 and 2026, it would experience a maximum of 146,000 af in combined shortage volumes and DCP contributions. The maximum total specified and total modeled Lower Basin combined shortage volumes and DCP contributions for calendar year 2024 for Action Alternative 2 would be 2.083 maf. In 2025 and 2026, the total potential Lower Division State combined shortage volumes and DCP contributions for Action Alternative 2 would be 4.000 maf a year.

Cumulative Effects

If one of the Glen Canyon Dam/Smallmouth Bass flow options were implemented, there would be no changes to water supply determinations. The operating tiers established by this SEIS would inform the Glen Canyon Dam flow rates and volumes. Therefore, no additive cumulative effects would occur on water supply determinations for Lower Division States due to operational changes evaluated in the EA.

Issue 4: How would changes to operational activities affect total water deliveries to the Lower Division States?

This section presents the water deliveries, i.e., modeled depletions, to the three Lower Division States. Deliveries to each state may deviate from a state's normal apportionment due to shortage or surplus conditions, DCP contributions, ICS creation and delivery, and other system conservation.

In addition to conditions encountered under the 2007 FEIS, more extreme hydrologic conditions may result in limitations on deliveries due to physical constraints on reservoir outflow capabilities at low-water elevations. Specifically, system shortages occur when Lake Mead's elevation reaches dead pool (elevation 895 feet). Under the extreme low elevation reservoir conditions, Lake Mead may not be able to meet all downstream demands.

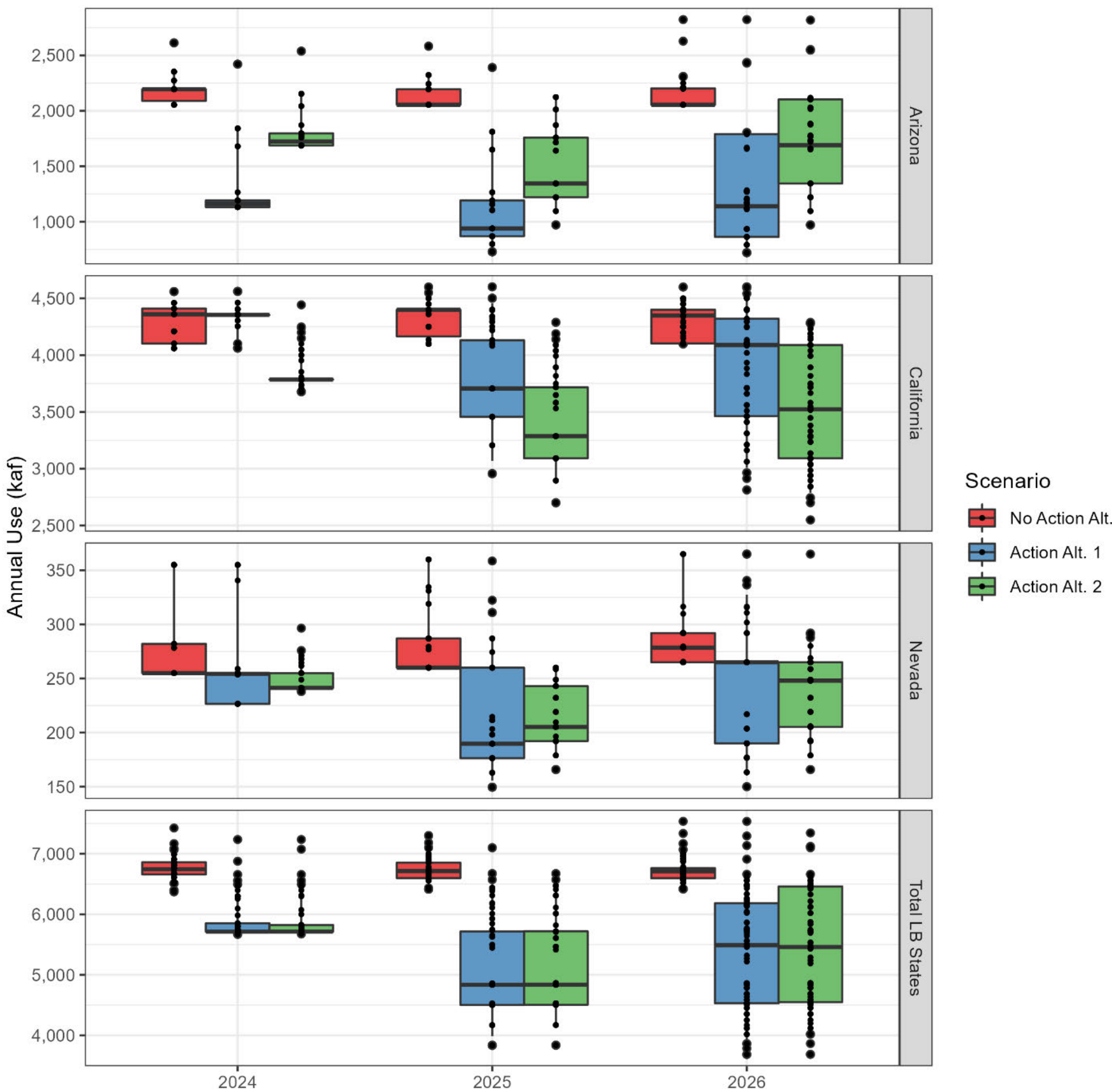
Summary of Alternatives

Under the No Action Alternative, the median modeled depletions remain relatively similar with little variability because Lake Mead is typically projected to be below 1,025 feet with the maximum shortage and DCP contributions occurring below this elevation. The action alternatives almost always result in lower modeled depletions to Lower Division States than the No Action Alternative. However, it is important to note that these depletions do not take into account system shortages discussed below. In the action alternatives, median modeled depletions to the Lower Division States decrease through 2025 and then increase in 2026 (see **Figure 3-23**) as Lake Mead's elevation is stabilized and then it begins to increase in 2026.

Figure 3-23 shows the modeled depletions for the Lower Division States in 2024, 2025, and 2026. Each dot is the annual use volume produced by a single hydrologic trace, and dots may be plotted on top of one another. The boxes capture the 25th to 75th percentile of the modeled elevations and the whiskers extend to the 5th and 95th percentiles, with outliers represented as dots beyond these lines.

Comparing the modeled depletions between Action Alternative 1 and Action Alternative 2 across states shows the effects of distributing shortages based on priority (Action Alternative 1) versus distributing shortages based on an equal percentage (Action Alternative 2). Action Alternative 1 results in lower modeled depletions for Arizona and Nevada and higher modeled depletions to California relative to Action Alternative 2. Equivalently, Action Alternative 2 results in lower modeled depletions for California and higher modeled depletions for Arizona and Nevada relative to Action Alternative 1.

Figure 3-23
Lower Division State Modeled Depletions[11]



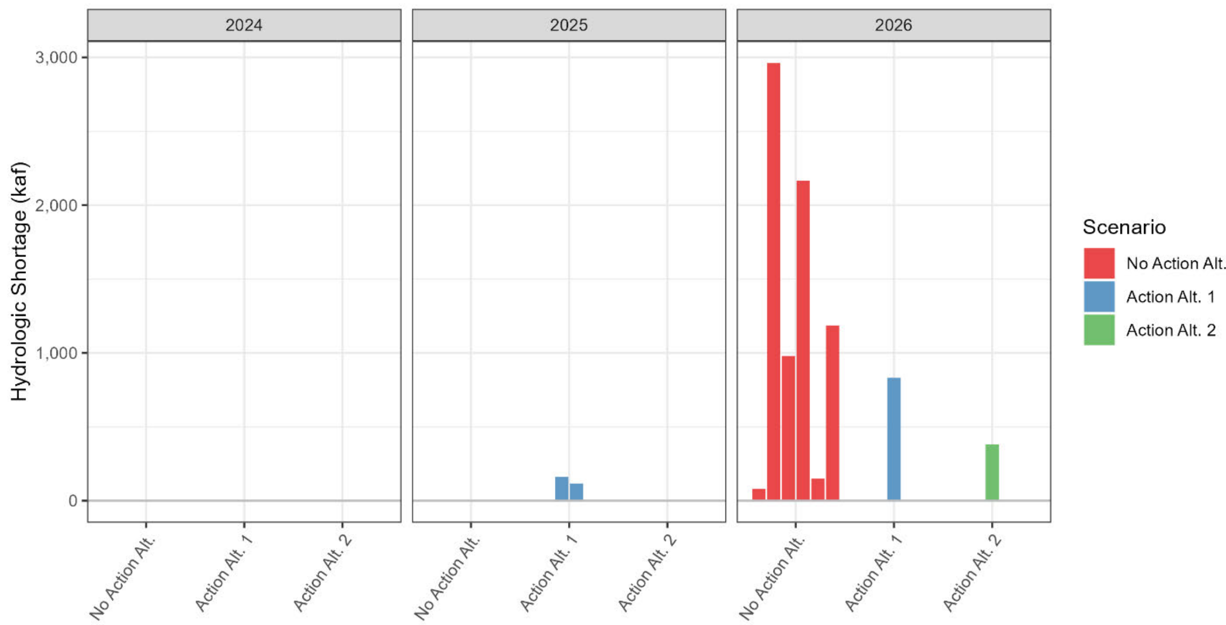
Importantly, both action alternatives decrease the frequency (**Table 3-14**) and magnitude (**Figure 3-24**) of system shortages, relative to the No Action Alternative. In 2026, 6.7 percent of No Action Alternative traces have a system shortage, which is reduced to 1.1 percent of traces in both action alternatives. When a system shortage does occur, the maximum volume exceeds 2.5 maf in the No Action Alternative, but it is only 830,000 af in Action Alternative 1 and 380,000 af in Action Alternative 2. In the No Action Alternative, system shortages would be expected to increase in frequency into the future as the elevation of Lake Mead continues to decline and not recover.

[11] Depletions modeled without system shortages.

Table 3-14
Percentage of Traces with System Shortages (Percent)

Year	No Action	Action Alternative 1	Action Alternative 2
2024	0	0	0
2025	0	2.2	0
2026	6.7	1.1	1.1

Figure 3-24
Range of Lower Basin System Shortages



No Action Alternative

The No Action Alternative assumes a continuation of the 2007 Interim Guidelines and 2019 DCPs. Shortages and DCP contributions are dependent on the projected January 1 Lake Mead elevation. **Table 3-11** includes total shortages and DCP contributions to the Lower Division States under all alternatives. Assumptions for ICS creation and delivery (see **Appendix C**) can also affect the modeled deliveries to the Lower Division States.

Figure 3-23 provides a comparison of Arizona, Nevada, and California's modeled depletions under the No Action Alternative and the action alternatives. In 2024–2026, the median total modeled depletions for the Lower Division States are 6.810 maf, 6.714 maf, and 6.682 maf, respectively. Total modeled depletions for Lower Division States under the No Action Alternative do not exhibit much variability, as over half the traces each year are below 1,025 feet at Lake Mead where the maximum combined shortage and DCP contributions of 1.1 maf occur. There are slightly fewer traces with larger depletions each year, as Lake Mead's elevation also exhibits a downward trend from 2023-2026. Deliveries lower than the modeled depletions shown in **Figure 3-23** can occur when Lake

Mead is at dead pool and it cannot meet all downstream demands. In these cases, system shortages are reported as a total for the entire Lower Basin. **Table 3-14** shows the percentage of traces in which a system shortage occurs under each alternative, with this occurring in 6.7 percent of traces in 2026 in the No Action Alternative. **Figure 3-24** shows the range of volumes of system shortage for 2024–2026 under each alternative across the entire Lower Basin, which can exceed 2.500 maf in 2026 under the No Action Alternative. Based on the projected trends, system shortages would be expected to increase in frequency into the future as the elevation of Lake Mead continues to decline and not recover.

Total Deliveries to Arizona

Water deliveries to Arizona are projected to fluctuate throughout the 3-year period of analysis; these fluctuations reflect variations in hydrologic conditions and the physical constraints of Lake Powell and Lake Mead. Under the No Action Alternative, modeled annual depletions for Arizona are shown in **Figure 3-23**. In 2024, the median modeled depletions total 2.195 maf, and in 2025 and 2026, the median modeled depletions total 2.055 maf. The model indicates a similar pattern to that of the entire Lower Basin; deliveries will be greater initially, but they will decline as less water is available in storage and more traces fall below 1,025 feet.

Total Deliveries to Nevada

Water deliveries to Nevada are projected to fluctuate throughout the 3-year period of analysis; these fluctuations reflect variations in hydrologic conditions and the physical constraints of Lake Powell and Lake Mead. Under the No Action Alternative, modeled annual depletions for Nevada are shown in **Figure 3-23**. In 2024–2026, the median deliveries are 255,000 maf, 260,000 maf and 278,000 maf, respectively. The model indicates a similar pattern for Nevada as for that of the entire Lower Basin; deliveries will initially be greater, but they will decline as less water is available in storage and more traces fall below 1,025 feet.

Total Deliveries to California

Water deliveries to California are not expected to be impacted greatly under the No Action Alternative. However, the model indicates deliveries will fluctuate throughout the 3-year period of analysis; these fluctuations reflect variations in hydrologic conditions and the physical constraints of Lake Powell and Lake Mead. Under the No Action Alternative, modeled annual depletions for California are shown in **Figure 3-23**. In 2024–2026, the median deliveries are 4.360 maf, 4.400 maf and 4.349 maf, respectively. The model indicates a similar pattern to that of the entire Lower Basin, although the magnitude of impacts is less. This is because California does not make DCP contributions until Lake Mead is below 1,040 feet and these contributions are modeled to be made through ICS conversion, when possible. Most of the variability in California's deliveries in the No Action Alternative are due to modeled ICS creation and delivery.

Action Alternative 1

Action Alternative 1 includes reduced releases from Glen Canyon Dam, the use of physical elevations for tier determinations, and additional shortage volumes when Lake Mead is below 1,090 feet based exclusively on the concept of priority. Modeling assumptions for Action Alternative 1 are stated in **Section 3.3.8** and described in detail in **Appendix C**, CRMMS Model Documentation. Assumptions for ICS creation and delivery (see **Appendix C**) can also affect the modeled deliveries to the Lower Division States. **Table 3-11** includes total shortages and DCP contributions to the Lower Division States under all alternatives.

In 2024–2026, the median total deliveries modeled to the Lower Division States under Action Alternative 1 are 5.771 maf, 4.836 maf, and 5.494 maf, respectively. Modeled deliveries to the Lower Division States are reduced relative to the No Action Alternative, due to the additional shortages included in Action Alternative 1. Modeling the distributing of shortages exclusively based on the concept of priority results in Arizona (and Nevada to a lesser extent) incurring the bulk of the additional shortages. However, reservoir elevations remain higher, resulting in more reliable deliveries farther in the time horizon, as shown by the reduced chance of system shortages due to reaching dead pool at Lake Mead. 2.2 percent of traces in 2025 and 1.1 percent of traces in 2026 experience system shortages under Action Alternative 1, as shown in **Table 3-14**. **Figure 3-24** shows the range of volumes of system shortage for 2024–2026 under each alternative across the entire Lower Basin. No system shortages are modeled in 2024, while in 2025 system shortages range from 117,000 to 161,000 af, and in 2026 only one trace shows a system shortage of 832,000 af.

Total Deliveries to Arizona

Under Action Alternative 1, modeled water deliveries to Arizona are projected to fluctuate throughout the 3-year period of analysis. These fluctuations reflect variations in hydrologic conditions, the physical constraints of Lake Powell and Lake Mead, and the shortage condition and DCP contributions based on the projected Lake Mead elevation. Modeled annual depletions for Arizona for Action Alternative 1 are shown in **Figure 3-23**. In 2024–2026, the median deliveries are 1.162 maf, 940,000 af, and 1.799 maf, respectively. Under Action Alternative 1, modeled deliveries to Arizona are limited by increased shortages, compared to the No Action Alternative; however, deliveries are more reliable later in the time horizon relative to the No Action Alternative due to a decrease in the frequency and volume of system shortages. This is because the additional shortages in Action Alternative 1 help stabilize and then increase Lake Mead's elevation.

Total Deliveries to Nevada

Under Action Alternative 1, modeled water deliveries to Nevada are projected to fluctuate throughout the 3-year period of analysis. These fluctuations reflect variations in hydrologic conditions, the physical constraints of Lake Powell and Lake Mead, and the shortage tier and DCP contributions based on the projected Lake Mead elevation. Modeled annual depletions for Nevada for Action Alternative 1 are shown in **Figure 3-23**. In 2024–2026, the median deliveries are 254,000 af, 190,000 af, and 265,000 af, respectively. Under Action Alternative 1, modeled deliveries to Nevada are limited by increased shortages, compared with the No Action Alternative; however, deliveries are more reliable later in the time horizon relative to the No Action Alternative, due to a decrease in the frequency and volume of system shortages. This is because the additional shortages in Action Alternative 1 help stabilize and then increase Lake Mead's elevation.

Total Deliveries to California

Under Action Alternative 1, modeled water deliveries to California are projected to fluctuate throughout the 3-year period of analysis. These fluctuations reflect variations in hydrologic conditions, the physical constraints of Lake Powell and Lake Mead, and the shortage tier and DCP contributions based on the projected Lake Mead elevation. Modeled annual depletions for California for Action Alternative 1 are shown in **Figure 3-23**. In 2024–2026, the median deliveries are 4.354 maf, 3.707 maf, and 4.089 maf, respectively. Under Action Alternative 1, modeled deliveries to California are limited by increased shortages, compared with the No Action Alternative, especially for 2025–2026. In 2024, the total Lower Basin shortages and DCP contributions are limited to 2.083 maf; at this level only a small portion of the additional shortage at certain elevations (see *Issue 6*) is applied to California. In 2025-2026, the modeled additional shortages increase beyond 2.083 maf to a maximum of 4.0 maf when Lake Mead is below 950 feet. At these larger levels of shortage, some of the additional shortage volume is applied to California, which is responsible for the approximately 650,000 af reduction in median delivery between 2024 and 2025. Deliveries are more reliable later in the time horizon relative to the No Action Alternative due to a decrease in the frequency and volume of system shortages. This is because the additional shortages in Action Alternative 1 help stabilize and then increase Lake Mead's elevation. Under Action Alternative 1, modeled impacts on deliveries to California (particularly in 2024) are lower in magnitude than they are for Arizona and Nevada. This is due to the priority-based shortage allocations that result in California incurring a lesser magnitude of shortages.

Action Alternative 2

Action Alternative 2 includes reduced releases from Glen Canyon Dam, the use of physical elevations for tier determinations, additional shortage volumes when Lake Mead is below 1,090 feet that are distributed in the same percentage across all Lower Basin water users, and the potential for additional inflow to Lake Powell based on potential DROA contributions modeling assumptions. Modeling assumptions for Action Alternative 2 are stated in **Section 3.3.8** and described in detail in **Appendix C**, CRMMS Model Documentation. Assumptions for ICS creation and delivery (see **Appendix C**) can also affect the modeled deliveries to the Lower Division States. **Table 3-11** includes total shortages and DCP contributions to the Lower Division States under all alternatives.

In 2024–2026, the median total deliveries modeled to the Lower Division States under Action Alternative 2 are 5.749 maf, 4.837 maf, and 5.461 maf, respectively. Modeled depletions for the Lower Basin are less in 2025–2026 for all states because of the additional shortages modeled in these years. Reservoir elevations remain higher than the No Action Alternative, particularly in 2026, due to the increased additional shortages in 2025-2026, resulting in more reliable deliveries further in the time horizon with a minimized chance of system shortages related to reaching dead pool at Lake Mead. Also, deliveries are projected to be greater in Action Alternative 2 due to how model assumptions for potential DROA releases affect Lake Powell releases which, in turn, can affect Lake Mead's operating condition. **Table 3-14** shows the percentage of traces in which a system shortage occurs under each alternative, with this occurring in 1.1 percent of traces in 2026, under Action Alternative 1. **Figure 3-24** shows the range of volumes of system shortage for 2024–2026 under each alternative across the entire Lower Basin. No system shortages are experienced in 2024 or 2025 under Action Alternative 2, while 380,000 af of system shortages are experienced in 2026.

Total Deliveries to Arizona

Under Action Alternative 2, modeled water deliveries to Arizona are projected to fluctuate throughout the 3-year period of analysis. These fluctuations reflect variations in hydrologic conditions, the physical constraints of Lake Powell and Lake Mead, and the shortage condition and DCP contributions based on the projected Lake Mead elevation. Modeled annual depletions for

Arizona for Action Alternative 2 are shown in **Figure 3-23**. In 2024–2026, the median deliveries are 1.723 maf, 1.345 maf, and 1.690 maf, respectively. Under Action Alternative 2, modeled deliveries to Arizona are limited by increased shortages, compared to the No Action Alternative; however, deliveries are more reliable later in the time horizon relative to the No Action Alternative due to a decrease in the frequency and volume of system shortages. This is because the additional shortages in Action Alternative 2 help stabilize and then increase Lake Mead's elevation.

Total Deliveries to Nevada

Under Action Alternative 2, modeled water deliveries to Nevada are projected to fluctuate throughout the 3-year period of analysis. These fluctuations reflect variations in hydrologic conditions, the physical constraints of Lake Powell and Lake Mead, and the shortage condition and DCP contributions based on the projected Lake Mead elevation. Modeled annual depletions for Nevada for Action Alternative 2 are shown in **Figure 3-23**. In 2024–2026, the median deliveries are 241,000 af, 205,000 af, and 248,000 af, respectively. Under Action Alternative 2, modeled deliveries to Nevada are limited by increased shortages, compared with the No Action Alternative; however, deliveries are more reliable later in the time horizon relative to the No Action Alternative due to a decrease in the frequency and volume of system shortages. This is because the additional shortages in Action Alternative 2 help stabilize and then increase Lake Mead's elevation.

Total Deliveries to California

Under Action Alternative 2, modeled water deliveries to California are projected to fluctuate throughout the 3-year period of analysis. These fluctuations reflect variations in hydrologic conditions, the physical constraints of Lake Powell and Lake Mead, and the shortage condition and DCP contributions based on the projected Lake Mead elevation. Modeled annual depletions for California for Action Alternative 2 are shown in **Figure 3-23**. In 2024–2026, the median deliveries are 3.785 maf, 3.287 maf, and 3.523 maf, respectively. Under Action Alternative 2, modeled deliveries to California are limited by increased shortages, compared with the No Action Alternative, especially for 2025–2026.

Deliveries are more reliable later in the time horizon relative to the No Action Alternative due to a decrease in the frequency and volume of system shortages. This is because the additional shortages under Action Alternative 2 help stabilize and then increase Lake Mead's elevation. Under Action Alternative 1, modeled impacts on deliveries to California (particularly in 2024) are greater in magnitude than they are for Arizona and Nevada. This is due to additional shortage volumes being distributed in the same percentage across all Lower Basin water users.

Cumulative Effects

If one of the Glen Canyon Dam/Smallmouth Bass flow options were implemented, there would be no additional changes to water deliveries. The operating tiers established by this SEIS would inform the Glen Canyon Dam flow rates and volumes. Therefore, no additive cumulative effects would occur on water deliveries for Lower Division States due to the flow options.

Issue 5: How would changes to operational activities affect deliveries to Mexico?

As stated above, Mexico's reductions and recoverable savings are per Minute 323, with a maximum of 275,000 af (of their 1,500,000 af annual water allotment), when Lake Mead is below elevation

1,025 feet. This differs from the assumed 16.67 percent of the total shortage analyzed in the 2007 FEIS. The amount of water modeled for delivery to Mexico during each calendar year has been set in accordance with the 1944 Water Treaty and Minute 323. The alternatives in this analysis do not change the specified reductions and recoverable savings to Mexico as outlined in Minute 323; however, the action alternatives do affect projected Lake Mead elevations (through modeled changes to Lake Powell's release and increased Lower Division State shortages). These differences in Lake Mead elevation can result in different modeled reductions and recoverable savings for Mexico.

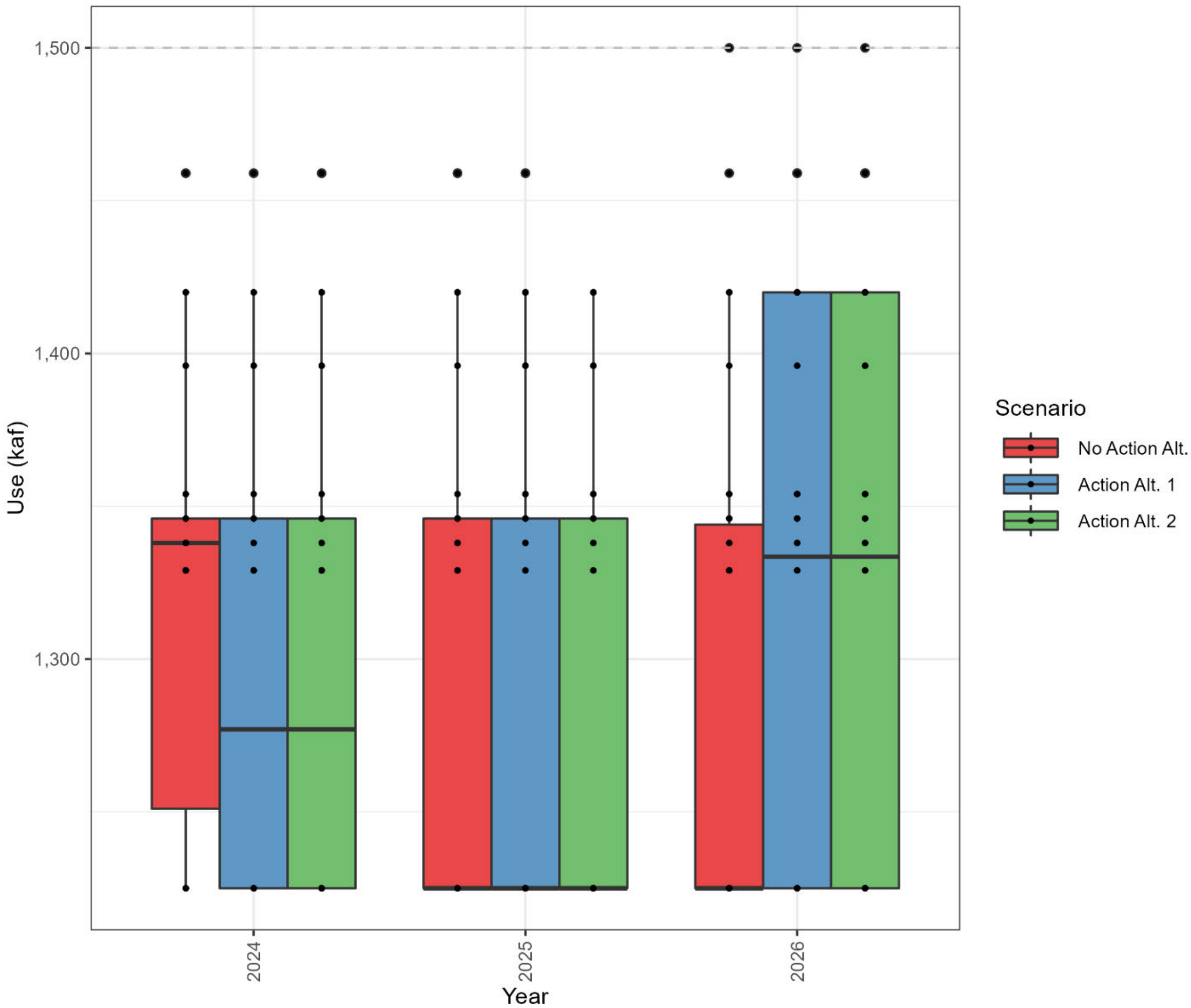
Figure 3-25 compares the modeled deliveries to Mexico for the No Action and action alternatives. The No Action Alternative shows a median delivery to Mexico of 1.338 maf in 2024, decreasing to 1.225 maf in 2025 and 2026. Both action alternatives show median deliveries to Mexico of approximately 1.275 maf in 2024, 1.225 maf in 2025, and approximately 1.334 maf in 2026. These deliveries are consistent with the Lake Mead elevations shown in **Figure 3-8**, which shows lower elevations in the action alternatives in 2024, but higher elevations by 2026. Deliveries lower than the modeled depletions shown in **Figure 3-23** could occur if Lake Mead is at dead pool and it cannot meet all downstream demands. In these cases, system shortages at dead pool are reported as a total for the entire Lower Basin (**Figure 3-24**).

Figure 3-25 shows the modeled deliveries to Mexico for the No Action Alternative and action alternatives in 2024, 2025, and 2026. Each dot is the annual delivery volume produced by a single hydrologic trace, and dots may be plotted on top of one another. The boxes capture the 25th to 75th percentile of the modeled elevations and the whiskers extend to the 5th and 95th percentiles, with outliers represented as dots beyond these lines.

Cumulative Effects

If one of the Glen Canyon Dam/Smallmouth Bass flow options were implemented, there would be no changes to water deliveries to Mexico. The operating tiers established by this SEIS would inform the Glen Canyon Dam flow rates and volumes. Therefore, no additive cumulative effects would occur on water deliveries for Lower Division States due to operational changes evaluated in the EA.

Figure 3-25
Modeled Range of Deliveries to Mexico after Minute 323 Reductions and Savings



Issue 6: How would changes to operational activities affect the modeled distribution of shortages to and within the Lower Division States?

Summary of Alternatives

Lower Division States' shortage distributions discussed under this issue, were modeled with the Shortage Allocation Models to quantify estimated shortage distributions. Overall, the No Action Alternative does not analyze the same magnitude of shortage as Action Alternative 1 and Action Alternative 2. Both action alternatives apply to 2007 Interim Guidelines shortages and 2019 DCPs contributions; however, additional shortages, as modeled in this SEIS, are applied differently in the action alternatives. Action Alternative 1 models additional shortages based on priority, both among the Lower Division States and within each state, and Action Alternative 2 models the distribution of additional shortages using the same percentage across all Lower Basin water users. Total Lower Division States' shortages of up to 1.100 maf were analyzed under the No Action Alternative. Under Action Alternative 1 and Action Alternative 2, total Lower Division States' shortages of up to 2.083

maf were analyzed for 2024. Under Action Alternative 1 and Action Alternative 2, up to 4.000 maf of shortage was analyzed for 2025 and 2026. Modeling details for each alternative are described in **Section 3.3.8** and **Appendix D**, Shortage Allocation Model Documentation.

Under the No Action Alternative, the maximum total volume of 2007 Interim Guidelines shortages and 2019 DCP contributions modeled was 1.1 maf in 2024-2026. The maximum shortage and DCP contributions for Arizona and Nevada are 720,000 af and 30,000 af, respectively. The maximum DCP contributions for California are 350,000 af.

Under Action Alternative 1, the total volume of the 2007 Interim Guidelines shortages and 2019 DCP contributions modeled was 2.083 maf in 2024. The maximum shortage and DCP contributions modeled under Action Alternative 1 for Arizona was 1.74 maf reducing the total available water for the Arizona 4th priority to 0. The maximum shortage and DCP contributions modeled under Action Alternative 1 for Nevada was 83,000 af. The maximum shortage and DCP contributions modeled under Action Alternative 1 for California was 261,000 af.

Under Action Alternative 2, the total volume of 2007 Interim Guidelines shortages, 2019 DCP contributions, and additional shortage modeled was 2.083 maf in 2024. The maximum shortage and DCP contributions modeled under Action Alternative 2 for Arizona was 1.09 maf. The maximum shortage and DCP contributions modeled under Action Alternative 2 for Nevada were 69,300 af. The maximum shortage and DCP contributions modeled under Action Alternative 2 for California was 926,000 af.

No Action Alternative

The No Action Alternative models shortages and contributions, consistent with the 2007 Interim Guidelines and 2019 DCPs, among the Lower Division States. There is a different assumption, as compared to the 2007 FEIS, for how shortage distribution can be modeled that takes into consideration fulfilling PPRs before distributing shortage among the Lower Division States. Additional information on the differences can be found in **Appendix B** and **Appendix D**, Shortage Allocation Model Documentation. (Refer to **Section 3.17.2** for specific Tribal allocations under the No Action Alternative.)

Distribution of Shortages within Arizona

Table 3-15 provides a summary of the total shortage impacts modeled for Arizona, broken out by the range of analyzed shortage volumes under the No Action Alternative for 2024–2026. Total basin shortage volumes analyzed under the No Action Alternative for the Lower Division States ranged from 200,000 af to 1.1 maf. This resulted in 192,000 af to 720,000 af in shortages for Arizona in accordance with the 2007 Interim Guidelines and 2019 DCPs. As the total shortage analyzed increases, there is a corresponding increase in shortages allocated to Arizona 4th-priority entitlement holders including CAP contracts and subcontracts. The maximum shortage volume simulated does not exceed Stage 1 shortage amounts. (Refer to **Appendix D**, Shortage Allocation Model Documentation for additional information.)

Table 3-15
No Action Alternative - Shortage Impacts Modeled for Arizona by Priority

Summary of Shortage Impacts by State and Priority	**Range of Analyzed Volumes of Total Shortage to Lower Division States**							
Arizona – Priority	**200,000**	**533,000**	**617,000**	**867,000**	**917,000**	**967,000**	**1,017,000**	**1,100,000**
5th, 6th, and CAP Agricultural and Other Excess	192,000	294,465	335,708	338,687	338,687	338,687	338,687	330,681
4th Priority I (Mainstream)	0	0	0	0	0	0	0	18,520
4th Priority ii (CAP)[1]								
NIA Priority	0	217,535	245,633	245,633	245,633	245,633	245,633	245,633
M&I Priority	0	0	0	32,302	32,302	32,302	32,302	80,877
Indian Priority	0	0	10,659	23,378	23,378	23,378	23,378	44,289
2nd and 3rd Priorities	0	0	0	0	0	0	0	0
1st Priority (PPR)	0	0	0	0	0	0	0	0
Subtotal	**192,000**	**512,000**	**592,000**	**640,000**	**640,000**	**640,000**	**640,000**	**720,000**

Note: This analysis does not reflect an operational estimate of when water may cease to be physically available to certain users.
Note: Orange highlights indicate the level at which available water for a priority is reduced to zero.
Note: Refer to **Appendix D**, Shortage Allocation Model Documentation for additional information.
[1]Water for AZ P5 (unused) and P6 (surplus) contracts is not available during shortage and for the purposes of this analysis these contracts are assumed not to be fulfilled. Agricultural and other CAP excess contracts do not confer a Colorado River water entitlement and cannot be exercised under any of the scenarios modeled here.

Disclaimer: These modeling results for the No Action Alternative should only be used to compare the relative magnitude of effects reasonably expected to occur under the alternatives evaluated in this SEIS. Modeling assumptions should not be taken as agency position with respect to contract or statutory interpretation. The modeling assumptions are not intended to limit Secretarial discretion with respect to current or future policy. This model is not a substitute for the annual process of reviewing water orders and determining which can be filled, and it cannot replicate the precision required of that process.

Distribution of Shortages within Nevada

Table 3-16 provides a summary of the total shortage impacts modeled for Nevada, broken out by the range of analyzed shortage volumes under the No Action Alternative for 2024–2026. Total basin shortage volumes analyzed under the No Action Alternative for the Lower Division States ranged from 200,000 af to 1.1 maf. This ultimately resulted in 8,000 af to 30,000 af in shortages for Nevada in accordance with the 2007 Interim Guidelines and 2019 DCPs. There is a corresponding increase in shortages allocated to Nevada (up to 30,000 af), but only at the 8th-priority level. The maximum shortage volume simulated does not exceed Stage 1 shortage amounts. (Refer to **Appendix D**, Shortage Allocation Model Documentation for additional information.)

Distribution of Shortages within California

Table 3-17 provides a summary of the total shortage impacts modeled for California broken out by the range of analyzed shortage volumes under the No Action Alternative for 2024–2026. Total basin shortage volumes analyzed under the No Action Alternative for the Lower Division States ranged from 200,000 af to 1.1 maf. This resulted in 0 af to 350,000 af in shortages for California, which are attributed to only 2019 DCP contributions. (Refer to **Appendix D**, Shortage Allocation Model Documentation for additional information.)

Action Alternative 1

The Action Alternative 1 Shortage Allocation Model calculated total shortages and the distribution of shortage within the priority system among and within the Lower Division States. The model analyzed shortage volumes of up to 2.083 maf for 2024. Under Action Alternative 1, available water is distributed first among states and subsequently among the entitlement holders based on priority within each state. Under this alternative, shortages are characterized by two stages, Stage 1 and Stage 2. (Refer to modeling assumptions in **Section 3.3.8** for descriptions on Stage 1 and Stage 2 shortages.) There is a different assumption, as compared to the 2007 FEIS, for how shortage distribution can be modeled that takes into consideration fulfilling PPRs before distributing shortage among the Lower Division States. Additional information on these assumptions can be found in **Appendix B** and **Appendix D**, Shortage Allocation Model Documentation. (Refer to **Section 3.17.2** for specific Tribal allocations under Action Alternative 1.)

Table 3-16
No Action Alternative–- Shortage Impacts Modeled for Nevada by Priority

Summary of Shortage Impacts by State and Priority	Range of Analyzed Volumes of Total Shortage to Lower Division States							
Nevada – Priority	**200,000**	**533,000**	**617,000**	**867,000**	**917,000**	**967,000**	**1,017,000**	**1,100,000**
8th Priority (SNWA – Balance and Unused)	8,000	21,000	25,000	27,000	27,000	27,000	27,000	30,000
8th Priority (SNWA and Big Bend)	0	0	0	0	0	0	0	0
7th Priority (Boy Scouts, Reclamation, and Nevada Department of Wildlife)	0	0	0	0	0	0	0	0
6th Priority (Las Vegas Valley Water District)	0	0	0	0	0	0	0	0
5th Priority (PABCO and Lakeview Company)	0	0	0	0	0	0	0	0
4th Priority (Henderson and Basic Management)	0	0	0	0	0	0	0	0
3rd Priority (Boulder City)	0	0	0	0	0	0	0	0
2nd Priority (LMNRA)	0	0	0	0	0	0	0	0
1st Priority (PPRs: LMNRA and Fort Mojave Indian Reservation)	0	0	0	0	0	0	0	0
Subtotal	**8,000**	**21,000**	**25,000**	**27,000**	**27,000**	**27,000**	**27,000**	**30,000**

Note: This analysis does not reflect an operational estimate of when water may cease to be physically available to certain users.

Note: Refer to **Appendix D**, Shortage Allocation Model Documentation for additional information.

Disclaimer: These modeling results for the No Action Alternative should only be used to compare the relative magnitude of effects reasonably expected to occur under the alternatives evaluated in this SEIS. Modeling assumptions should not be taken as agency position with respect to contract or statutory interpretation. The modeling assumptions are not intended to limit Secretarial discretion with respect to current or future policy. This model is not a substitute for the annual process of reviewing water orders and determining which can be filled, and they cannot replicate the precision required of that process.

Table 3-17
No Action Alternative - Shortage Impacts Modeled for California by Priority

Summary of Shortage Impacts by State and Priority	Range of Analyzed Volumes of Total Shortage to Lower Division States							
California – Priority	**200,000**	**533,000**	**617,000**	**867,000**	**917,000**	**967,000**	**1,017,000**	**1,100,000**
4th Priority (MWD)	0	0	0	200,000	250,000	300,000	350,000	350,000
3rd Priority (IID, Coachella Valley Water District, Palo Verde Irrigation District, and QSA Diversions by MWD)	0	0	0	0	0	0	0	0
2nd Priority (Yuma Project Reservation Division)	0	0	0	0	0	0	0	0
1st Priority (Palo Verde Irrigation District)	0	0	0	0	0	0	0	0
PPRs	0	0	0	0	0	0	0	0
Subtotal	**0**	**0**	**0**	**200,000**	**250,000**	**300,000**	**350,000**	**350,000**

Note: This analysis does not reflect an operational estimate of when water may cease to be physically available to certain users.
Note: Refer to **Appendix D**, Shortage Allocation Model Documentation for additional information.

Disclaimer: These modeling results for the No Action Alternative should only be used to compare the relative magnitude of effects reasonably expected to occur under the alternatives evaluated in this SEIS. Modeling assumptions should not be taken as agency position with respect to contract or statutory interpretation. The modeling assumptions are not intended to limit Secretarial discretion with respect to current or future policy. This model is not a substitute for the annual process of reviewing water orders and determining which can be filled, and they cannot replicate the precision required of that process.

Distribution of Shortages within Arizona

Table 3-18 displays Lower Division States' shortage volumes for 2024 and the portions of these shortage amounts that were assumed by Reclamation to be distributed to Arizona. Available water within Arizona is distributed among a number of water users based on Arizona's Colorado River priority system.

Under Action Alternative 1, the total Basin shortage volumes modeled for the Lower Division States ranged from 400,000 af to 2.083 maf for 2024. This results in 384,000 af to 1.738 maf in shortages for Arizona. At the first tier of shortage analyzed (400,000 af), shortages are distributed to CAP NIA priority long-term contracts, with no water available for Arizona 5th and 6th priority entitlement holders, entitlement holders for unused CAP water, and CAP agricultural and other excess entitlement holders. As the total shortage analyzed increases, there is a corresponding increase in shortages allocated to Arizona and its 4th-priority entitlement holders. The allocation of shortages to individual users within the CAP is affected by the priority system within the CAP. (Refer to **Appendix D** for additional information regarding CAP shortages.)

As total shortages to the Lower Division States increase, the impact of a given shortage to the CAP increasingly impacts the higher-priority Indian and M&I priority contractors and subcontractors, and the shortage cannot be absorbed by the lower priorities. Shortages to the Lower Division States that total approximately 1.734 maf or greater result in shortages to Arizona 2nd- and 3rd-priority entitlement holders. These shortages are characterized as Stage 1 (where Arizona is assigned 96 percent up to 1.67 maf) and Stage 2 (where Arizona is assigned 19.6 percent of additional shortages).

Distribution of Shortages within Nevada

Table 3-19 shows Lower Division States' shortage volumes and the portion of the shortage that is allocated to Nevada for 2024. The total Basin shortage volumes analyzed for the Lower Division States ranged from 400,000 af to 2.083 maf for 2024. This results in 16,000 af to 83,300 af in shortages for Nevada. These shortages are borne, as described in the No Action Alternative above, but with increasing volumes of shortage imposed on 8th Priority entitlement holders.

Nevada bears a reduction of 4.0 percent of the total Lower Division States shortage volume under Stage 1 shortage. In addition to its Stage 1 shortage, Nevada bears 4.0 percent of the Stage 2 Shortage.

Distribution of Shortages within California

Table 3-20 shows different Lower Division States' shortage volumes and the portion of the shortage that is allocated to California for 2024. At the 2.083[12] maf analyzed shortage volume, the shortage allocation to California represents approximately 12.6 percent of the total Lower Division States' shortage amount in 2024. This shortage is only borne by 4th Priority entitlement holders.

[12] Refer to **Section 2.7** for additional information. Because the 2019 DCP contributions for California exceed the 2024 total shortage and contribution volume as modeled by the Shortage Allocation Model, the sum of the three states' totals exceeds the total shortage and contribution volume. While total amount of the three states' total shortage and contribution volume exceeds 2.083 maf in the elevation tiers below elevation 1,035 feet, the ROD would not exceed a total shortage and contribution volume of 2.083 maf in 2024.

Table 3-18
Action Alternative 1 - Summary of Shortages for Arizona 2024

Summary of Wet Water Shortage Impacts by State and Priority		Range of Analyzed Volumes of Total Shortage to Lower Division States*				
		400,000	**1,066,000**	**1,234,000**	**1,734,000**	**2,083,000**
Arizona	**Priority**					
	5th, 6th, and CAP Agricultural and Other Excess	286,465	333,921	339,609	351,774	365,748
	4th Priority i (Mainstream)	0	32,228	39,643	63,122	63,445
	4th Priority ii (CAP)[1]					
	NIA Priority	97,535	245,633	245,633	245,633	245,633
	M&I Priority	0	265,389	360,827	602,601	602,601
	Indian Priority	0	146,189	198,928	332,533	332,533
	2nd and 3rd Priorities	0	0	0	68,977	128,127
	1st Priority (PPRs)	0	0	0	0	0
	Subtotal	**384,000**	**1,023,360**	**1,184,640**	**1,664,640**	**1,738,087**

Note: Orange highlights indicate the level at which available water for a priority is reduced to zero.

Note: Refer to **Appendix D**, Shortage Allocation Model Documentation, for additional information.

[1]Water for AZ P5 (unused) and P6 (surplus) contracts is not available during shortage and for the purposes of this analysis these contracts are assumed not to be fulfilled. Agricultural and other CAP excess contracts do not confer a Colorado River water entitlement and cannot be exercised under any of the scenarios modeled here.

Disclaimer: These modeling results (for Action Alternative 1) should only be used to compare the relative magnitude of effects reasonably expected to occur under the alternatives evaluated in this SEIS. Modeling assumptions should not be taken as agency position with respect to contract or statutory interpretation, and they are not intended to limit Secretarial discretion with respect to current or future policy. This model is not a substitute for the annual process of reviewing water orders and determining which can be filled and cannot replicate the precision required of that process.

Table 3-19
Action Alternative 1 - Summary of Modeled Shortages for Nevada 2024

Summary of Wet Water Shortage Impacts by State and Priority		Range of Analyzed Volumes of Total Shortage to Lower Division States*				
		400,000	**1,066,000**	**1,234,000**	**1,734,000**	**2,083,000**
Nevada	**Priority**					
	8th Priority (SNWA - Balance & Unused)	16,000	42,640	49,360	69,360	83,320
	8th Priority (SNWA and Big Bend)	0	0	0	0	0
	7th Priority (Boy Scouts, Reclamation, and Nevada Department of Wildlife)	0	0	0	0	0
	6th Priority (Las Vegas Valley Water District)	0	0	0	0	0
	5th Priority (PABCO and Lakeview Company)	0	0	0	0	0
	4th Priority (Henderson and Basic Management)	0	0	0	0	0
	3rd Priority (Boulder City)	0	0	0	0	0
	2nd Priority (LMNRA)	0	0	0	0	0
	1st Priority (PPRs: LMNRA and Fort Mojave Indian Reservation)	0	0	0	0	0
	Subtotal	**16,000**	**42,640**	**49,360**	**69,360**	**83,320**

Note: Refer to **Appendix D**, Shortage Allocation Model Documentation, for additional information.

Disclaimer: These modeling results (for Action Alternative 1) should only be used to compare the relative magnitude of effects reasonably expected to occur under the alternatives evaluated in this SEIS. Modeling assumptions should not be taken as agency position with respect to contract or statutory interpretation, and they are not intended to limit Secretarial discretion with respect to current or future policy. This model is not a substitute for the annual process of reviewing water orders and determining which can be filled, and they cannot replicate the precision required of that process.

Table 3-20
Action Alternative 1 - Summary of Shortages for California for 2024

Summary of Wet Water Shortage Impacts by State and Priority		Range of Analyzed Volumes of Total Shortage to Lower Division States				
		400,000	**1,066,000**	**1,234,000**	**1,734,000**	**2,083,000**
California[1]	**Priority**					
	4th Priority (MWD)	0	0	0	0	261,593
	3rd Priority (IID, Coachella Valley Water District, Palo Verde Irrigation District, and QSA Transfers to MWD)	0	0	0	0	0
	2nd Priority (Yuma Project Reservation Division)	0	0	0	0	0
	1st Priority (Palo Verde Irrigation District)	0	0	0	0	0
	PPRs	0	0	0	0	0
	Subtotal	**0**	**0**	**0**	**0**	**261,593**

Note: Refer to **Appendix D**, Shortage Allocation Model Documentation, for additional information
[1]The first increment of shortage volumes required by Action Alternative 1 is satisfied by 2019 DCP contributions. In some elevation tiers, the 2019 DCP contributions for California exceed the 2024 shortage volume under Action Alternative 1, which follows the priority system. In these instances, the Shortage Allocation Model for the No Action Alternative will show higher shortages to California than the Shortage Allocation Model for Action Alternative 1.

Disclaimer: These modeling results (for Action Alternative 1) should only be used to compare the relative magnitude of effects reasonably expected to occur under the alternatives evaluated in this SEIS. Modeling assumptions should not be taken as agency position with respect to contract or statutory interpretation, and they are not intended to limit Secretarial discretion with respect to current or future policy. This model is not a substitute for the annual process of reviewing water orders and determining which can be filled, and they cannot replicate the precision required of that process.

Action Alternative 2

The Action Alternative 2 Shortage Allocation Model calculated total shortages and the effects of distributing shortages using the same percentage across all Lower Basin water users within the Lower Division States. The model analyzed shortage volumes to the Lower Division States beginning at 400,000 af and going up to 2.083 maf for 2024. **Table 3-21** summarizes the range of shortage volumes analyzed, the range of total additional shortage analyzed, and the percentage reduction to each water user. Under Action Alternative 2, shortages are in addition to current commitments (2007 Interim Guidelines shortages and 2019 DCP contributions) and they are distributed in the same percentage across all Lower Basin water users based on 2021 consumptive use (and conservation), and volumes of water available are calculated relative to that baseline. Under this alternative, first, the 2007 Interim Guidelines shortages and 2019 DCP contributions are applied assuming that they are borne by the major junior priority diverter in each state and second,, the additional shortages are applied to all Lower Basin water users using the same percentage; this percentage reduction is shown in the tables below. The reductions for each state are broken out as irrigation, domestic, and Tribal user group totals in **Table 3-22** through **Table 3-24**. (Refer to **Appendix D**, Shortage Allocation Model Documentation for additional information regarding how shortages are distributed and for a full list of water users.) (Refer to **Section 3.17.2** for specific Tribal allocations under Action Alternative 2.)

Distribution of Shortages within Arizona

Table 3-22 summarizes Lower Division States' shortage volumes and the portions of these shortage amounts that were assumed by Reclamation to be distributed to Arizona. The total Basin shortage volumes analyzed for the Lower Division States ranged from 400,000 af to 2.083 maf. This results in 266,000 af to 1.075 maf in shortages for Arizona. As the volume of additional shortage analyzed increases, there is a corresponding increase in the reductions to each water user group.

Distribution of Shortages within Nevada

Table 3-23 provides Lower Division States' shortage volumes and the portions of these shortage amounts that were assumed by Reclamation to be distributed to Nevada. Under Action Alternative 2, the total Basin shortage volumes analyzed for the Lower Division States ranged from 400,000 af to 2.083 maf. This results in 16,000 af to 74,000 af in shortages for Nevada. As the volume of additional shortage analyzed increases, there is a corresponding increase, on average, in the reductions to each water user group.

Distribution of Shortages within California

Table 3-24 provides Lower Division States' shortage volumes and the portions of these shortage amounts that were assumed by Reclamation to be distributed to California. Under Action Alternative 2, the total Basin shortage volumes analyzed for the Lower Division States ranged from 400,000 af to 2.083 maf. This results in 117,000 af to k934,000 af in shortages for California. As the volume of additional shortage analyzed increases, there is a corresponding increase, on average, in the reductions to each water user group.

Table 3-21
Action Alternative 2 - Summary of Shortage Impacts

	Range of Analyzed Volumes							
Range of Analyzed Volumes of Total Shortage to Lower Division States (af)	**400,000**	**1,066,000**	**1,234,000**	**1,734,000**	**2,083,000**	**2,083,000**	**2,083,000**	**2,083,000**
Range of Analyzed Volumes of Total Additional Shortage to Lower Division States (af)	200,000	533,000	617,000	867,000	983,000	1,066,000	1,116,000	1,166,000
Percentage Reduction to Each Water User's 2021 Adjusted Consumptive Use	**2.67%**	**7.11%**	**8.23%**	**11.56%**	**13.11%**	**14.21%**	**14.88%**	**15.55%**

Source: Reclamation 2023g

Disclaimer: These modeling results (for Action Alternative 2) should only be used to compare the relative magnitude of effects reasonably expected to occur under the alternatives evaluated in this SEIS. Modeling assumptions should not be taken as agency position with respect to contract or statutory interpretation, and are not intended to limit Secretarial discretion with respect to current or future policy. This model is not a substitute for the annual process of reviewing water orders and determining which can be filled, and they cannot replicate the precision required of that process.

Table 3-22
Action Alternative 2 -Summary of Shortages for Arizona

		Range of Analyzed Volumes							
		400,000	**1,066,000**	**1,234,000**	**1,734,000**	**2,083,000**	**2,083,000**	**2,083,000**	**2,083,000**
Arizona	**Percentage Reduction**	**2.67%**	**7.11%**	**8.23%**	**11.56%**	**13.11%**	**14.21%**	**14.88%**	**15.55%**
	Irrigation[1]	256,590	382,819	390,887	420,840	429,640	435,715	441,984	448,253
	Domestic (Includes Interim Guidelines and DCPs)[1]	1,402	131,899	198,120	261,644	330,406	293,925	300,453	306,980
	Tribal[1]	8,675	196,269	233,339	281,195	326,941	308,333	314,203	320,073
	Subtotal	**266,667**	**710,987**	**822,347**	**963,680**	**1,086,987**	**1,037,973**	**1,056,640**	**1,075,307**

[1] 2007 Interim Guidelines shortages, DCP contributions, and additional reductions are distributed among irrigation, domestic, and Tribal users as part of the CAP priority system. In California and Nevada, 2007 Interim Guidelines shortages and DCP contributions are attributed to the junior priority domestic diverter.

Disclaimer: These modeling results (for Action Alternative 2) should only be used to compare the relative magnitude of effects reasonably expected to occur under the alternatives evaluated in this SEIS. Modeling assumptions should not be taken as agency position with respect to contract or statutory interpretation, and they are not intended to limit Secretarial discretion with respect to current or future policy. This model is not a substitute for the annual process of reviewing water orders and determining which can be filled, and they cannot replicate the precision required of that process.

Table 3-23
Action Alternative 2 -Summary of Shortages for Nevada

		Range of Analyzed Volumes							
		400,000	**1,066,000**	**1,234,000**	**1,734,000**	**2,083,000**	**2,083,000**	**2,083,000**	**2,083,000**
Nevada	**Percentage Reduction**	**2.67%**	**7.11%**	**8.23%**	**11.56%**	**13.11%**	**14.21%**	**14.88%**	**15.55%**
	Irrigation	0	0	0	0	0	0	0	0
	Domestic (Includes Interim Guidelines and DCPs)[1]	15,919	42,104	49,430	61,329	68,922	69,208	71,188	73,168
	Tribal	81	216	250	351	398	432	452	472
	Subtotal	**16,000**	**42,320**	**49,680**	**61,680**	**69,320**	**69,640**	**71,640**	**73,640**

[1] 2007 Interim Guidelines shortages, DCP contributions, and additional reductions are distributed among irrigation, domestic, and Tribal users as part of the CAP priority system. In California and Nevada, 2007 Interim Guidelines shortages and DCP contributions are attributed to the junior priority domestic diverter.

Disclaimer: These modeling results (for Action Alternative 2) should only be used to compare the relative magnitude of effects reasonably expected to occur under the alternatives evaluated in this SEIS. Modeling assumptions should not be taken as agency position with respect to contract or statutory interpretation, and they are not intended to limit Secretarial discretion with respect to current or future policy. This model is not a substitute for the annual process of reviewing water orders and determining which can be filled, and it cannot replicate the precision required of that process.

Table 3-24
Action Alternative 2 -Summary of Shortages for California

		Range of Analyzed Volumes							
		400,000	**1,066,000**	**1,234,000**	**1,734,000**	**2,083,000**	**2,083,000**	**2,083,000**	**2,083,000**
California	**Percentage Reduction**	**2.67%**	**7.11%**	**8.23%**	**11.56%**	**13.11%**	**14.21%**	**14.88%**	**15.55%**
	Irrigation	91,233	243,135	281,452	395,493	448,408	486,269	509,077	531,886
	Domestic (Includes Interim Guidelines and DCPs)[1]	25,827	68,829	79,676	311,960	476,939	487,658	444,114	400,571
	Tribal	274	730	845	1,187	1,346	1,460	1,528	1,597
	Subtotal	**117,333**	**312,693**	**361,973**	**708,640**	**926,693**	**975,387**	**954,720**	**934,053**

[1] 2007 Interim Guidelines shortages, DCP contributions, and additional reductions are distributed among irrigation, domestic, and Tribal users as part of the CAP priority system. In California and Nevada, 2007 Interim Guidelines shortages and DCP contributions are attributed to the junior priority domestic diverter.

Disclaimer: These modeling results (for Action Alternative 2) should only be used to compare the relative magnitude of effects reasonably expected to occur under the alternatives evaluated in this SEIS. Modeling assumptions should not be taken as agency position with respect to contract or statutory interpretation, and they are not intended to limit Secretarial discretion with respect to current or future policy. This model is not a substitute for the annual process of reviewing water orders and determining which can be filled, and it cannot replicate the precision required of that process.

Cumulative Effects
If one of the Glen Canyon Dam/Smallmouth Bass flow options were implemented, there would be no additional changes to the distribution of shortages. The operating tiers established by this SEIS would inform the Glen Canyon Dam flow rates and volumes. Therefore, no additive cumulative effects would occur on water deliveries for Lower Division States due to operational changes evaluated in the EA.

3.8 Water Quality

3.8.1 Affected Environment

This section describes the water quality constituents that could potentially be affected by the alternatives. These water quality constituents of concern are:

- salinity
- temperature
- sediment
- nutrients and algae
- dissolved oxygen
- metals
- perchlorate

This section describes historical and existing condition changes that have occurred since the 2007 FEIS was published. (For more information on the water quality constituents and historic conditions prior to 2007, refer to the 2007 FEIS.) While other water quality-related issues and parameters were also considered, they were determined unlikely to be affected by the alternatives or there was insufficient data to provide an assessment and they are not discussed here.

Salinity

Historically, salinity has been a concern for the Basin. High salinity causes damage across agricultural, municipal, and industrial sectors in the US, and it negatively impacts municipal and agricultural users in Mexico (USGS 2021). (See the 2007 FEIS for more information.)

The salinity criteria for the Colorado River have not been updated since the 2007 FEIS was published. The Colorado River Basin Salinity Control Forum continues to review and make recommendations for the salinity criteria for the Colorado River every 3 years (Colorado River Basin Salinity Control Forum 2020). **Table 3-25** shows the current salinity criteria for the Colorado River.

While salinity in the Colorado River has generally decreased over the past century (USGS 2021), salinity has only slightly decreased since 2007. Salinity control results from the implementation of measures on private agricultural lands. Programs like the Basin States Program and the US Department of Agriculture's Environmental Quality Incentives Program provide cost share assistance to landowners who install salinity control measures (Reclamation 2022a). Despite these salinity control efforts, there has been a consistent slowing of downward trends since 2000 (Rumsey 2021).

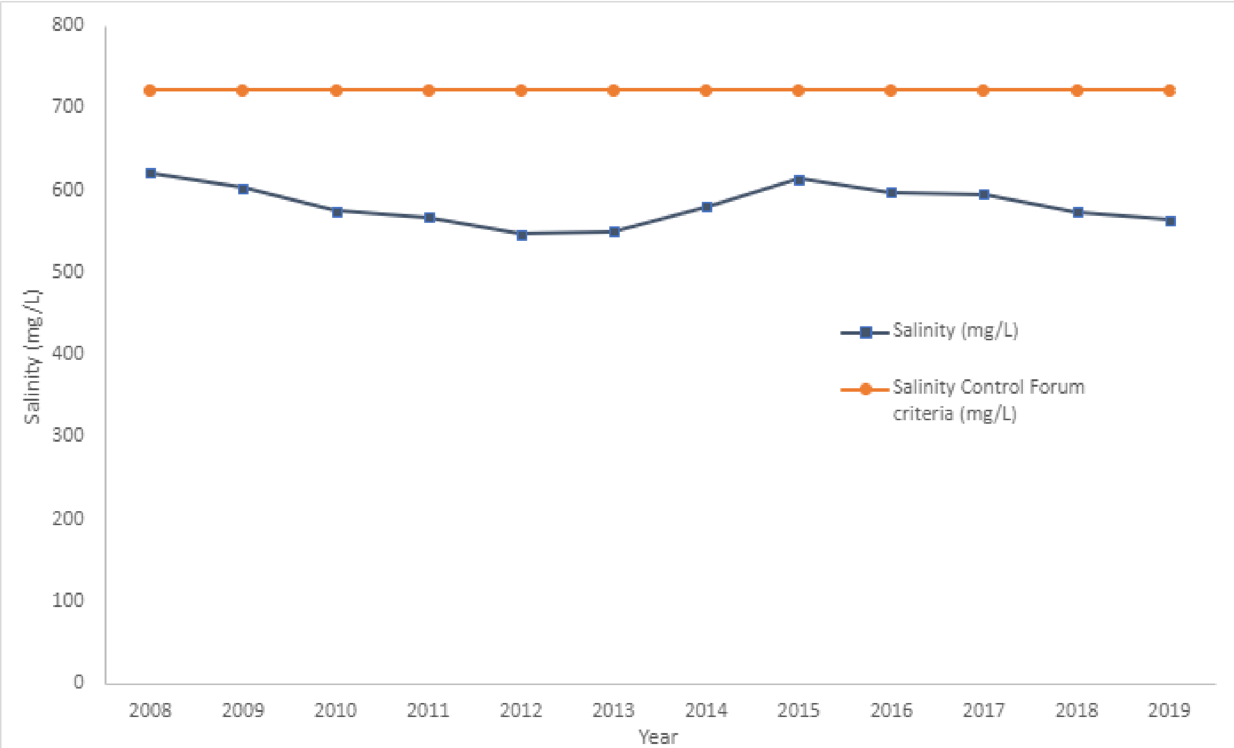
When the 2007 FEIS was released, salinity downstream of Glen Canyon Dam varied between 390 milligrams per liter (mg/L) to 660 mg/L; while, more recently, salinity has varied between 300 mg/L to 600 mg/L (Reclamation and NPS 2016). It is important to note that releases from lower elevations in Lake Powell are cooler and more saline compared to releases from higher through the penstocks of Glen Canyon Dam (Reclamation and NPS 2016). In a review of sampling efforts from 2007-2019, Reclamation has not exceeded the salinity criteria for the Colorado River, which is described in **Table 3-25**. At the time of this report, data was not available after 2019 (Reclamation 2019a). (See **Figure 3-26**, **Figure 3-27**, and **Figure 3-28** for more information and historical salinity concentrations in the Lower Basin.)

Table 3-25
Salinity Criteria for the Colorado River

Station	Flow-weighted average annual salinity (mg/L)
Below Hoover Dam	723
Below Parker Dam	747
At Imperial Dam	879

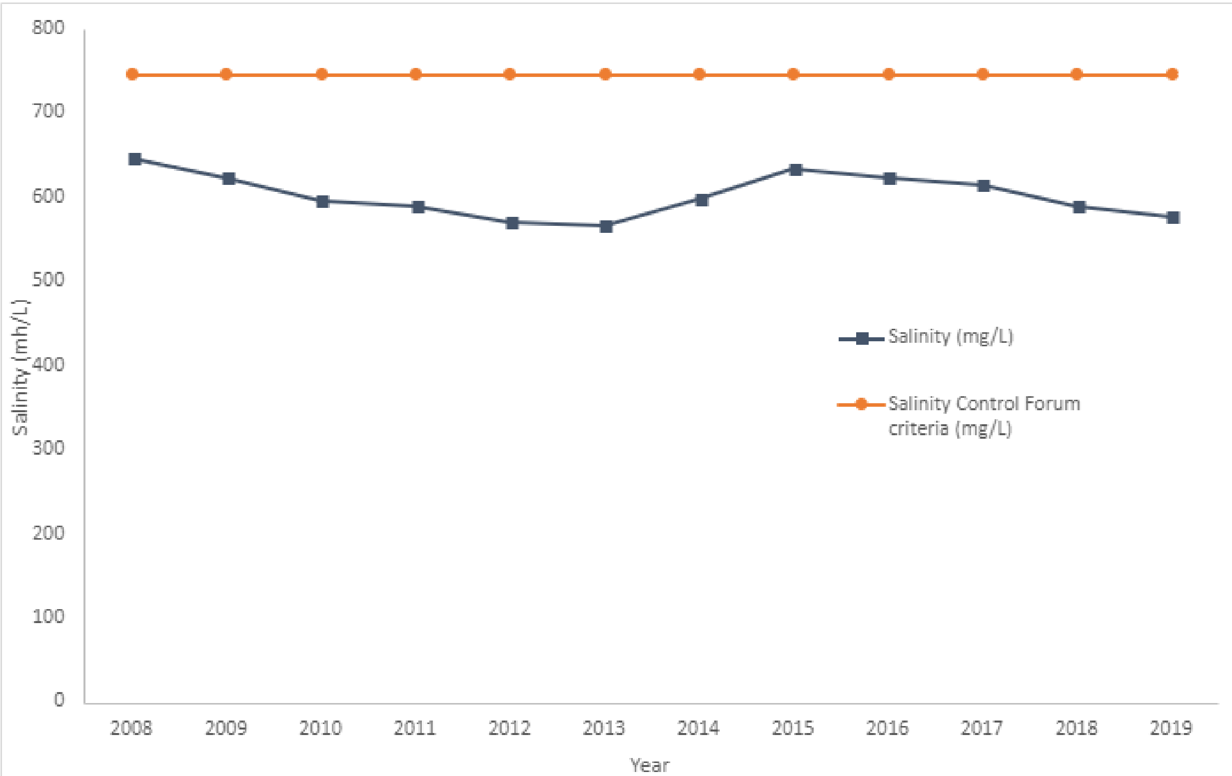
Source: Colorado River Salinity Control Forum 2020.

Figure 3-26
Colorado River Salinity Concentrations and Flows Downstream of Hoover Dam 2007–2019



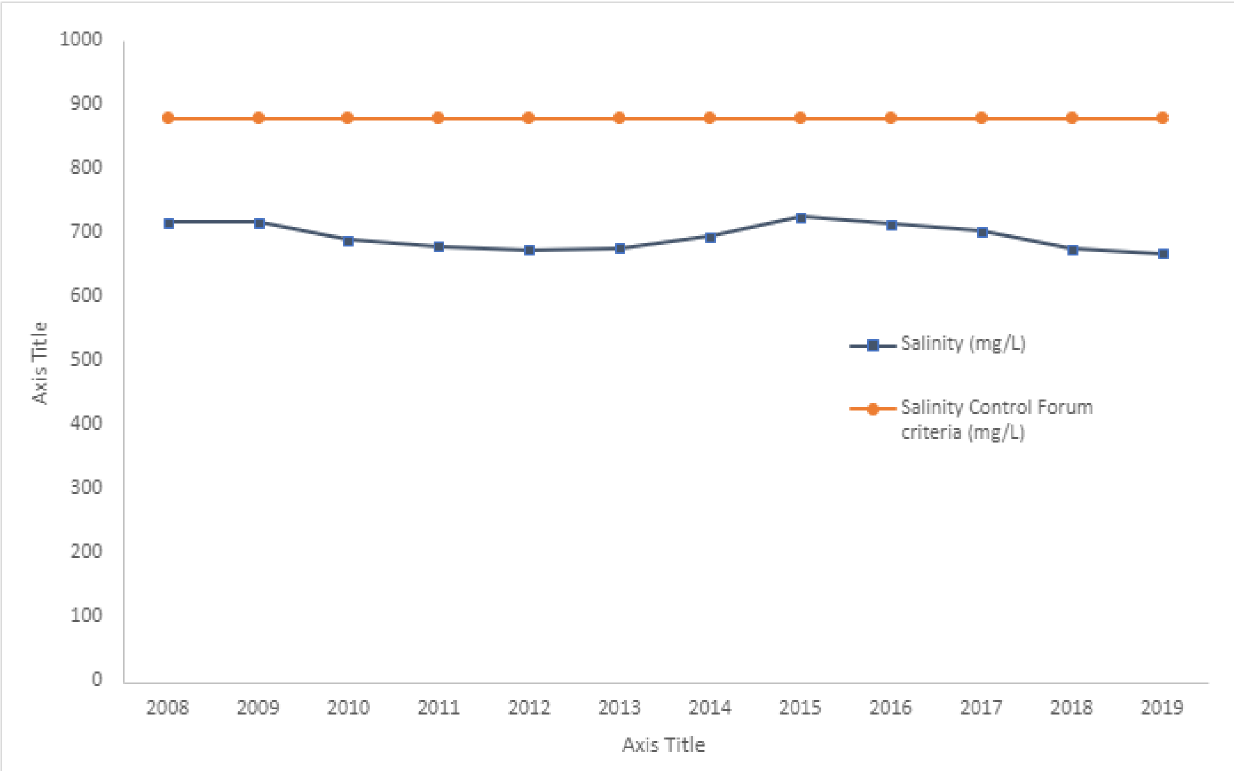
Source: Colorado River Basin Salinity Control Forum 2020

Figure 3-27
Colorado River Salinity Concentrations and Flows Downstream of Parker Dam 2007–2019



Source: Colorado River Basin Salinity Control Forum 2020

Figure 3-28
Colorado River Salinity Concentrations and Flows at Imperial Dam 2007–2019



Source: Colorado River Basin Salinity Control Forum 2020

Temperature

Since the early 2000s, drought conditions and lower water levels in Lake Powell have led to a general warming of water temperatures in the Colorado River below the Glen Canyon Dam (Reclamation and NPS 2016). Temperatures in the Colorado River in Grand Canyon are highly variable over space and time, and they are primarily controlled by the discharge and temperature released from Glen Canyon Dam and solar radiation dynamics along the river corridor (Mihalevich et al., 2020). As water moves farther away from Glen Canyon Dam (e.g., below RM 88), the influence of release discharge and temperature on water temperature becomes less, and local meteorological conditions become more important in determining the heat budget. During summer periods, increases in water temperatures downstream of Glen Canyon Dam are attributed to solar radiation and air temperatures (Dibble et al. 2021). The water in the Colorado River generally warms 1 degree Celsius (˚C) for every 30 miles traveled downstream during warmer months of the year under specific discharge and meteorological conditions. Some variation in lateral warming also occurs, with warmer temperatures along the shoreline and cooler water in the deep, fast-moving areas (Reclamation and NPS 2016).

Lake Powell is thermally stratified through much of the spring, summer, and early fall, which means that Lake Powell is arranged into layers with distinct temperatures and chemical characteristics. Generally, Lake Powell's epilimnion, or uppermost layer, ranges from 25˚C-30˚C in the summer and may drop to 6˚C-10˚C in the winter. Lake Powell's hypolimnion, or deeper layer, ranges from 6˚C-9˚C. In the winter, the thermal stratification breaks down and Lake Powell experiences turnover, where the higher stratified layers mix with deeper waters. Full turnover does not occur every year, but partial turnover does. In the winter, the thermal stratification breaks down and Lake Powell experiences turnover, where the different layers mix to create relatively homogenous conditions throughout the water column (Reclamation and NPS 2016).

Lake Mead is also thermally stratified. The temperature that enters Lake Mead is influenced by the temperature of water released from Lake Powell (Reclamation and NPS 2016). Lake Mead's hypolimnion, or deepest layer, is around 12˚C year-round. Lake Mead's epilimnion, or uppermost layer, ranges from about 14˚C-29˚C in the spring, summer, and early fall, then drops to about 13˚C-15˚C in the winter (SNWA 2023). (For additional historical data, see the 2007 FEIS.)

Sediment

Sediments, as considered in this analysis, are those that are sand sized (0.06 to 2.0 millimeters) or smaller. High concentrations of fine suspended sediment (less than 0.06 millimeters) can increase the turbidity (cloudiness); a water quality measure that affects light penetration and photosynthesis for aquatic species. (See **Section 3.13.2** for a description of the effects of turbidity on fish.)

Downstream of Hoover Dam, large and infrequent sediment inputs from the Bill Williams River and the Gila River cause sediment loading and increased turbidity. Reclamation continues to implement dredging projects upstream of Imperial Dam and upstream of Laguna Dam to remove accumulated sediment and ensure efficient delivery of Colorado River water to downstream users (Reclamation 2021a and USGS 2022).

Sediment in the reach from Lake Powell to Lake Mead is dependent on a mass balance between sediment deposition, erosion, and storage. Sediment deposition occurs wherever there is more sediment influx than efflux (Grams et al. 2013). Sediment storage is a dynamic condition that varies based on the specific spatial and temporal scales considered; it can be increasing (net deposition), decreasing (net erosion), or at equilibrium.

Sand is deposited throughout the reach between Lake Powell and Lake Mead (in the Marble and Grand Canyons) in bars (or patches) on the riverbed, in eddies, and on terrace sandbars (Reclamation and NPS 2016). Sandbars and beaches are important for biological, cultural, and recreational resources along the Colorado River. They form the substrate for the limited riparian vegetation in the arid environment (Hazel et al. 2022). Low elevation sandbars create zones of low velocity aquatic habitat (backwaters) that juvenile native fish utilize (Grams et al. 2010). These low elevation sandbars are also a source of sand for wind transport that may help protect archaeological resources (Sankey et al. 2022). In addition, beaches provide camping areas for river and backcountry users (Hazel et al. 2022).

Sandbars continuously exchange sand with the Colorado River. Thus, the sandbars commonly found along the banks of the Colorado River are generally dynamic and unstable. Since 1996, Reclamation has continued to conduct HFE releases to manage limited sediment resources to maintain or increase sandbar size. HFEs are experiments designed to improve sediment deposition, in which water releases from Glen Canyon Dam are much larger than the base flow that is typically released. HFEs are the only existing mechanism for producing river stages high enough to contribute to significant sandbar building. As regulated under LTEMP, Reclamation uses two, 6-month sediment accounting windows, or periods (one during the fall and one during the spring). These are used to evaluate whether the sediment mass balance is optimal for sandbar building prior to HFE implementation. HFE releases between 34,000 and 37,000 cfs or greater that are necessary for sandbar deposition (increased sandbar size), and sandbars erode between these events (Hazel et al. 2022). Reservoir drawdown and low flows, in conjunction with reduced sand deposition in eddies and on sandbars, have resulted and continue to result in net erosion of sand in this reach (USGS 2011 and USGS 2018).

River stage also affects the area of sand available for aeolian (wind) transport, as lower flows expose larger areas of bare sediment that can be mobilized by wind. Once sand has been exposed (not inundated) for a period of three consecutive days, that sand is approximately as mobile as the sand which was not previously inundated (Sankey et al. 2022).

Turbidity is known to increase in this reach during large sediment inputs from tributaries, such as the Paria River (USGS 2016), and during HFEs (Voichick and Topping 2010). As analyzed in the LTEMP Final EIS, turbidity increases due to erosion during HFEs are temporary and any observed fluctuations recover quickly when flows return to those less than those of an HFE magnitude (Reclamation and NPS 2016). These trends would continue under all the alternatives.

Nutrients and Algae

The 2007 FEIS described how deeper or hypolimnetic releases from Glen Canyon Dam are relatively nutrient rich, whereas epilimnetic or higher releases may cause a reduction of nutrients available to the downstream ecosystem. Nutrients, like nitrogen and phosphorus, are necessary for healthy aquatic ecosystems, but high levels of nutrients can cause algal blooms and poor water quality, threatening drinking water quality and harming aquatic life. Releases from Glen Canyon Dam and downstream Colorado River waters are generally low in nutrients, but inflows from tributaries typically contain warmer, nutrient-rich water that mixes with the Colorado River (Reclamation and NPS 2016). Total phosphorus samples at Lake Mead typically range from undetectable to 3.9 mg/L (SNWA 2023). Within Lake Mead, water within the Las Vegas Bay has the highest concentration of nutrients due to the discharge of wastewater effluent from the Las Vegas metropolitan area. Wastewater is a persistent contributor to the phosphorus needed to sustain algal growth, and stormwater with higher phosphorus contributions is an acute contributor. Since phosphorus is a limiting nutrient in the Colorado River system, these contributions support algal growth (USGS 2012). Additionally, lowering reservoir levels generally increases the concentration of nutrients and temperature levels, especially in shallow areas, which are more favorable for algal growth.

In Lake Mead in 2015, the increases in the temperatures of water entering Lake Mead led to a harmful algal bloom caused by a cyanobacteria, *Microcystis*, which may produce toxins that are harmful to humans, pets, and wildlife (Reclamation and NPS 2016). (See **Section 3.14** for information about harmful algal blooms impacts on recreation.)

No new TMDLs have been issued or evaluated for total phosphorus or ammonia in the Las Vegas Wash since the 2007 FEIS was published.

Dissolved Oxygen

Dissolved oxygen (DO) levels in Lake Powell and the Colorado River above Lee Ferry have been lower than historical levels in certain months over the last few years, but they are still within a similar average. Suspended sediment reduces DO in the inflow plume. This occurs whenever large sediment inputs occur and when sediment erodes from the reservoir banks. The Colorado River below Lee Ferry becomes oxygen saturated with mixing. The Colorado River DO increases approximately 1 mg/L between Glen Canyon Dam and Lee Ferry. This approximation can vary between negligible re-oxygenation and approximately 3 mg/L increases during very low oxygen releases during daylight hours (GCMRC 2023). DO levels below Glen Canyon Dam vary throughout the year, starting as low as 3.5 mg/L in the fall and rising as high as 9mg/L-10 mg/L in the spring (GCMRC 2023). This seasonal variation is due to changes in DO at the penstock level of Lake Powell during the year. In recent years, periods of low DO, which are less than 5 mg/L, have become more common due to lower lake elevations that expose sediment to erosion and resuspension.

Generally, Lake Powell DO concentrations are at their highest near the surface of the reservoir in the spring to early summer when inflows are well oxygenated and photosynthetic activities, atmospheric reaeration, and wind-induced mixing are high. As the year progresses, DO concentrations decrease during the summer into the fall, as a result of organic matter decomposition. DO gradually increases in the winter as a result of the higher oxygen-carrying capacity of cold water and the natural mixing processes that occur during turnover. The resulting discharged waters may eventually lead to higher DO in the downstream reach. Notably, when water is discharged through the river outlet works, such as during HFEs or the flow options evaluated here, it becomes well-aerated and increases the DO level. This aeration also occurs downstream of the Glen Canyon Dam in stretches of rapids (Reclamation and NPS 2016).

In Lake Mead, DO levels decrease in the bottom of the Las Vegas Basin as a result of high decomposition rates. Living algae in surface waters produce oxygen, then oxygen is consumed when the algae are decomposed in bottom waters. When greater nutrients and algae exist in surface water, the more decomposition and low oxygen in bottom waters, assuming a stratified system. Ongoing monitoring and investigations are being conducted to determine the cause of decreased DO concentrations in isolated sections, but the driver is likely higher temperatures from inflows. Backwaters in embayments have little water exchange and tend to be shallower and warmer. These conditions increase the likelihood of algae blooms and issues with low DO conditions, or hypoxia, when the algae die (Reclamation and NPS 2016). (See **Section 3.13,** Biological Resources for information about algal blooms' effects on wildlife.)

Metals

The 2007 FEIS described the sources of various metals, including selenium and mercury, within the planning area. Selenium and mercury are toxic to fish and wildlife and they can accumulate in the food web (Walters 2015). The Environmental Protection Agency (EPA) drinking water maximum contaminant level for mercury has not been updated since the 2007 FEIS; the MCL is 0.002 mg/L. The Lower Basin's selenium standard is 2 micrograms per liter (μg/L). The selenium in the Colorado River is about 1μg/L greater than the standard. There have been no significant changes to selenium or mercury since the 2007 FEIS was published.

The 2007 FEIS also described the soluble hexavalent chromium detected in groundwater in two known locations in the Lower Basin, at the former McCulloch Manufacturing Plant in Lake Havasu City, Arizona and at the Pacific Gas & Electric Compressor Station near Needles, California. Since 2007, mitigation efforts and plume monitoring have been ongoing. The latest groundwater monitoring data indicates that plume migration is not occurring (California Water Boards 2022). The landowner continues to monitor the chromium associated with the former McCulloch Manufacturing Plant at Lake Havasu Ave. and Holly Ave. Based on the latest site investigations, the groundwater chromium plume extended approximately 3,000 feet long and about 600 feet wide from the former McCulloch facility. This remained within the vicinity of the former McCulloch facility, which is several thousand feet from the Colorado River (Arizona Department of Environmental Quality 2022).

Perchlorate

The 2007 FEIS described the perchlorate contamination linked to a groundwater plume from the Kerr McGee Chemical Company in Henderson, Nevada. Since 2007, mitigating the perchlorate contamination has been an ongoing effort. The Nevada Division of Environmental Protection and the SNWA show a decreasing trend in perchlorate concentrations over the last decade, especially after point source remediation efforts began in 2002 (Hannoun and Tietjen 2022).

3.8.2 Environmental Consequences

Methodology

To understand the drivers of water quality change in Lake Powell, a 2D hydrodynamic model has been developed using CE-QUAL-W2 (Williams 2007) for salinity and total dissolved solids (TDS). Salinity is the measure of the amount of dissolved salt in water, where TDS measures all dissolved solids in a water sample, and it is a similar constituent as it estimates the level of salt within a water sample. TDS was used in the CE-QUAL-W2 model as a proxy for salinity. CE-QUAL-W2 uses hydrological and weather information to calculate the individual heat and constituent fluxes that contribute to reservoir mixing and stratification. To do this accurately, high-quality weather and hydrological information is needed. Additionally, high-quality bathymetric data are needed to build the model grid. Currently, the Lake Powell model is being redeveloped using updated bathymetric information (Jones and Root 2021). At the time of this modeling, the "new" version has only been tested for temperature and TDS fluxes, and it was still being calibrated for other constituents. Lake Powell modeling for the SEIS uses this new version and only simulates temperature and TDS within the reservoir. Unlike CRSS used in 2007, CRMMS does not include a module for salinity. Salinity inputs to the CE-QUAL-W2 Lake Powell model were generated using historic data and building Weighted Regressions on Time Discharge and Season models with a Kalman filter (Zhang and Hirsch 2019). Modeling with CE-QUAL-W2 was available for Glen Canyon Dam at the time of this report but additional modeling results from CE-QUAL-W2 and linear regression for Hoover Dam, Imperial Dam, and Parker Dam were not available at the time of this report.

A limited number of CRMMS traces were simulated due to time constraints associated with model run durations. Traces were identified that represented a range of different Lake Powell elevations, and they provided unique cases to test in the model. These cases included (1) the lowest elevation, (2) the lowest average elevation of traces that stay above power pool (3,490 feet), and (3) the highest elevation. These cases were determined for the No Action Alternative, Action Alternative 1, and Action Alternative 2 scenarios independently, but selected traces were paired between each scenario to allow for direct comparison among models. This resulted in a total of six pairs of traces that were run in CE-QUAL-W2.

The traces simulated with CE-QUAL-W2 were further compared against release temperature projections made with the Small Mouth Bass temperature model. The temperature modeling for smallmouth bass was carried out using a model that resamples daily Glen Canyon Dam forebay profiles projected by CE-QUAL-W2 between 2010 and 2023, herein referred to as the Small Mouth Bass model. The Small Mouth Bass model accounts for effects of reservoir elevation, inflow magnitude, and month of year when resampling temperatures from forebay profiles.

To project DO within Lake Powell and its water releases from Glen Canyon Dam, a long-term record of DO profiles from the reservoir forebay were used to model and project DO concentration within a 10-meter envelope of the penstock depth for the 180 hydrological traces generated as part of this effort. While the Lake Powell CE-QUAL-W2 does have a DO module (Williams 2007), recent observations suggested the need for its recalibration to improve performance under low water levels and with the aging of the reservoir.

A total of 132 water quality profiles from the months of August, September, and October (1967-2022) were used to calculate yearly mean late summer/early fall DO concentrations in six 10-meter layers of the Lake Powell water column (Deemer 2023). These represent the heights from which water could be drawn through the penstocks under the various hydrological traces being examined here (6 to <16 meters, 16 to <26 meters, 26 to <36 meters, 36 to <46 meters, 46 to <56 meters, and 56 to <66 meters). From these traces, linear models were built to project these water-layer-specific DO concentrations as a function of minimum reservoir elevation in that year, the volume of the spring inflow, which were calculated as the inflow from April-July, and the years since the reservoir was filled.

Net deposition of sediment in sandbars in the reach from Lake Powell to Lake Mead occurs when there is enough sand for sandbar building and when HFEs are conducted. USGS (Salter and Grams 2023) used the Mueller et al. 2021 Sandbar Model and the Wright et al. 2010 Sand Routing Model to project sandbar building and HFE implementation triggers. For the Sand Routing Model, USGS ran each hydrology trace with 22 possible Paria River sediment loads (the Paria River is a significant sediment source and tributary to the Colorado River), each associated with a 5-year period. The Sandbar Model was run with a subset of three Paria traces (1993–2003, 2011–2016, and 2017–2022), representing a large range of potential cumulative Paria sand load values. The Sandbar Model was calibrated to a set of the nine most dynamic sandbars out of the forty-five sandbars that are monitored long-term. The calibration period was 2015–2022. Historic and current (observation) data for sediment and flows from river mile (RM) 30 gage were used as inputs for the Sandbar model.. Observation data for Paria sediment load time series from RM30, RM61, and RM87 were used as inputs for the Sand Routing Model. For future projections, projected hourly flow releases from the WAPA Generation and Transmission Maximization Model (GTMax) Model and the Paria sediment load traces were used as inputs for the Sand Routing model. Sediment and flow data obtained from the Sand Routing Model at RM30 were then used to calculate the Sandbar Model future projections.

Assumptions

Under the CE-QUAL-W2 model, the testing of the "new" Lake Powell water quality model was carried out over a 12-year simulation period. This relatively long duration allowed for the evaluation of the influence modeling assumptions, such as the use of constant bathymetry and the omission of ephemeral tributary sources, which is important when modeling future climate change and/or hydrologic conditions. For this simulation, a combination of measured and modeled input data was used following the methods described by Mihalevich (2022). Reclamation provided hourly release data from Glen Canyon Dam penstocks and bypass outlets. Sub-hourly water quality data measured below Glen Canyon Dam near Page, Arizona (USGS gage #09379901) was used to evaluate model projections.

Release temperatures were evaluated based on 16°C and 20°C thresholds. When temperatures exceed a 16°C threshold for extended periods of time, the likelihood that smallmouth bass and other warmwater nonnatives increase in abundance is much higher, while when temperatures exceed 20 °C for longer periods of time it is expected to negatively impact salmonids. Smallmouth bass, and other warmwater nonnatives, pose a serious risk to native fish species in the Colorado River downstream of Glen Canyon Dam, while rainbow trout are a desired species for the Blue Ribbon fishery in the tailwater segment of Glen Canyon Dam. See **Section 3.13** for more information.

The DO model was based on the best model for projecting whole-metalimnion mean DO in the late summer and fall (Deemer 2023). In cases where the reservoir elevation was <3,490 feet, it was projected that a high end of 8 mg/L DO concentration would pass downstream. This assumption was based on the aeration that has been observed when water is spilled through the river outlet works (Hueftle and Stevens 2001; Vernieu 2010). Bypass releases of 15,009 cfs during the 2008 HFE resulted in supersaturated DO concentrations (12.6 mg/L; Vernieu 2010) below the Glen Canyon Dam, so we consider 8 mg/L DO a conservative estimate for spills under lower lake elevations (with bypass spill rates of 14,620 cfs at lake elevations of 3,490 feet and spill rates dropping at lower elevations. Future work to constrain the relationship between bypass spill rate and reaeration would help to more accurately model outflow DO concentrations resulting from bypass spill. This modeling exercise did not attempt to characterize monsoon-driven low DO events. Lake Powell can also develop low oxygen zones due to inputs from monsoon storms, as was observed in 2021.

The Sandbar and Sand Routing Models used an HFE magnitude of 40,000 cfs, with the assumption that low lake levels are likely to limit the maximum capacity (45,000 cfs) that can be released from Glen Canyon Dam. The Sandbar Model assumes a constant exponential erosion rate that is independent of discharge. It does not capture enhanced erosion rates from elevated flows. Though sand is available in the river at flows greater than the river stage (8,000 cfs), it can only be deposited on sandbars at or below the river stage. Dam operations do not allow for sustained discharges lower than 5,000 cfs at night and 8,000 cfs during the day (Reclamation and NPS 2016). Some of the hydrology traces include discharges below these minimums; however, the model was conditioned such that HFEs would not be implemented if discharges were below the minimums. The Sandbar Model is calibrated to yield the volume of sand at and above the 8,000 cfs river stage. Some traces include elevated sustained dam releases (20,000–30,000 cfs) that are projected to produce some sandbar growth; however, given that sandbars can only be built at and below the river stage, these deposits would occur at low elevations that would not be usable for beaches (camping uses). The

Sand Routing Model projects there is a relationship between sand export and HFE duration; that is, sediment loss occurs as the HFE duration increases. To find the sediment-triggered HFE duration, the sand routing model results are used to generate a simplified relationship between HFE duration and sand export.

Impact Indicators

For all alternatives evaluated, the following indicators were used to assess impacts.

- **Elevation protection:** Changes due to elevation protection with reservoir elevations that were not analyzed in the 2007 FEIS.
- **Low flows:** Changes to river flows that were not analyzed in the 2007 FEIS.
- **Upper Basin drought:** Changes due to drought in the Upper Basin that were not analyzed in the 2007 FEIS.

Constituents Excluded from Analysis

Since the 2007 FEIS was released, perchlorate containment and reduction strategies have continued to contribute to declining detectable concentrations of perchlorate in Lake Mead, Willow Beach, Lake Havasu, and other sampling locations in the lower Colorado River, as well as in areas using Colorado River water in Arizona. From sampling completed in Lake Mead from 2013 to 2023, perchlorate concentrations ranged from non-detectable levels to 5.6 parts per billion (ppb) (SNWA 2023).

Since conditions have improved and remediation efforts are ongoing, perchlorate was not brought forward for analysis.

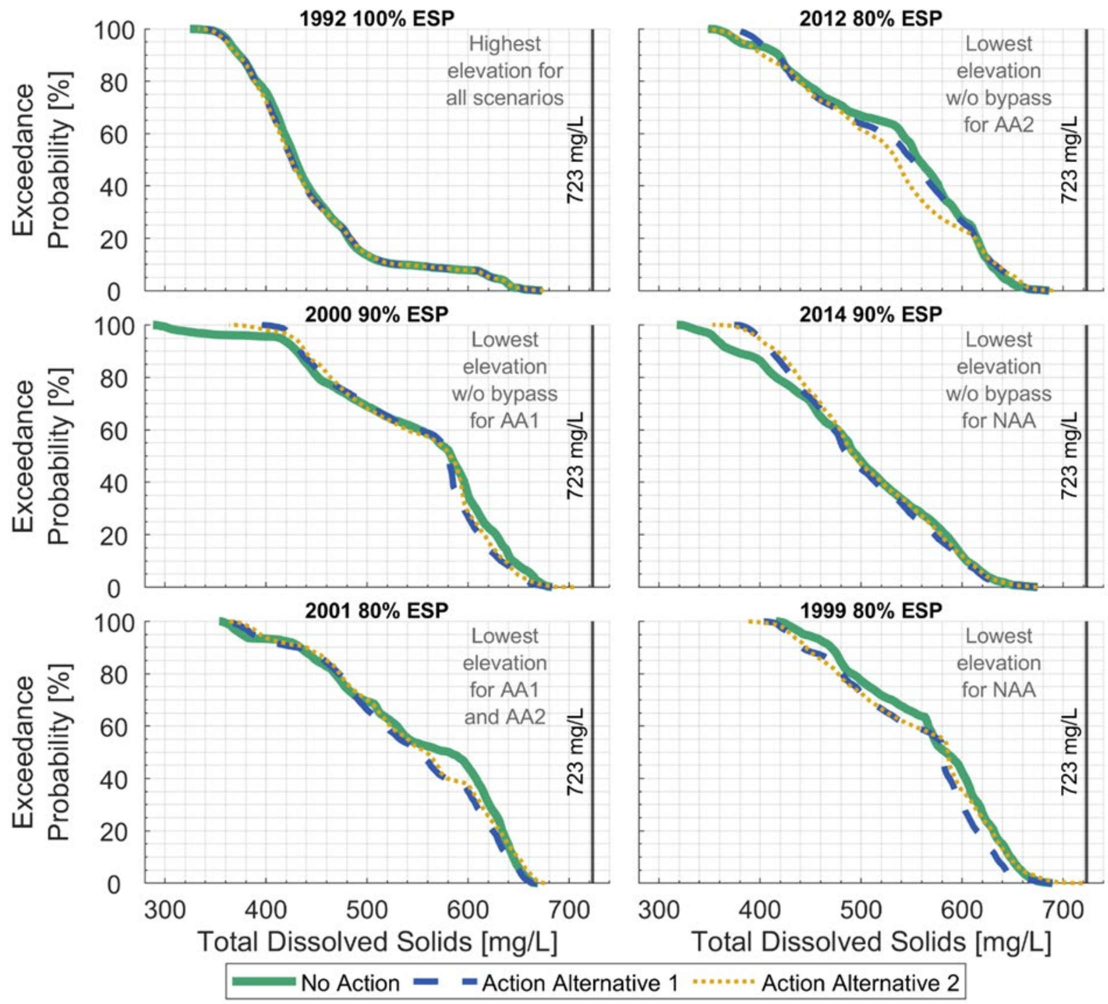
Issue 1: How would elevation protection and low-flow conditions affect salinity within each reach?

Summary

There is no limit for salinity concentration in waters released from Glen Canyon Dam; however, Hoover Dam has a limit of 723 mg/L as seen in **Table 3-25**. There is cyclical relationship between the salinity of inflows to Lake Powell and the salinity of waters below Hoover Dam that typically follows a two-year lag. These salinity levels are a major factor driving salinity in Lake Mead (Tillman et al. 2019). While this report cannot speak to modeled salinity concentrations in Lake Mead and releases from Hoover Dam, as seen in **Figure 3-29**, under every alternative, future salinity of Glen Canyon Dam releases would not exceed the numeric salinity criteria set for Hoover Dam. The CE-QUAL-W2 2D hydrodynamic model results also illustrated a general trend between Lake Powell elevation and salinity concentrations. Generally, when Lake Powell's elevations were high (trace 1992 100 percent ESP), salinity releases were lowest. Conversely, Lake Powell's elevations at 3,500 feet or lower resulted in high projected salinity concentrations as seen in **Figure 3-29**. (For a description of the six traces chosen, see the *Methodology* section.)

Under the No Action Alternative, Lake Powell is much more likely to reach dead pool, 3,370 feet. If Lake Powell were to reach dead pool, it would lead to an increase in salinity. (See **Section 3.4**, Hydrologic Resources, for more information.)

Figure 3-29
Exceedance Probability for Salinity*Concentrations in Glen Canyon Dam Releases



Source: USGS 2023a

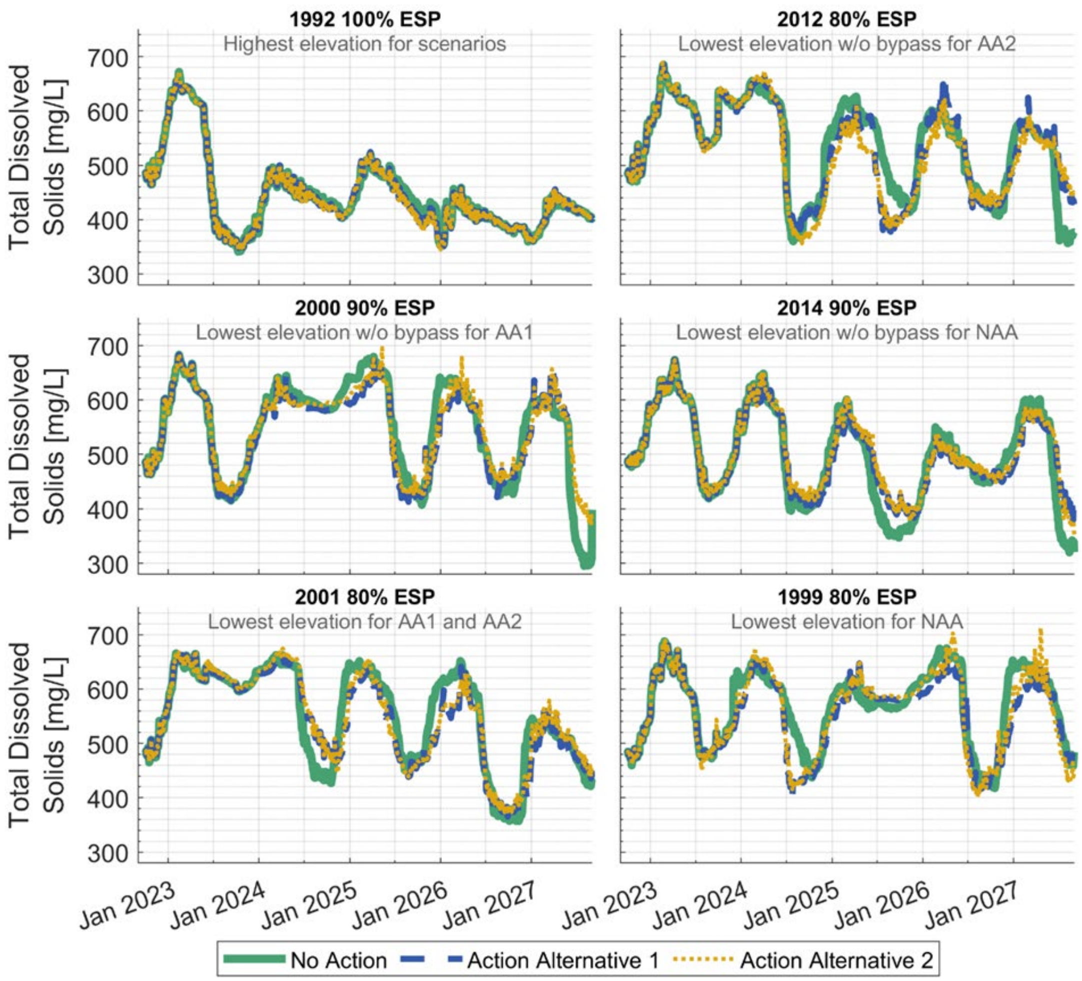
* Salinity is the measure of the amount of dissolved salt in water, where TDS measures all dissolved solids in a water sample, and it is a similar constituent as it estimates the level of salt within a water sample. TDS was used in the CE-QUAL-W2 model as a proxy for salinity.

No Action Alternative

Under the No Action Alternative, salinity concentrations in waters released from Glen Canyon Dam would not exceed 723 mg/L, which is the numeric salinity criteria for Hoover Dam as seen in **Figure 3-29**. While Glen Canyon Dam releases are related to the salinity concentrations at Lake Mead and in the waters below Hoover Dam, these modeling results do not represent Hoover Dam release concentrations.

Figure 3-30 further illustrates the trend between Lake Powell elevations and salinity concentrations with higher lake levels resulting in marginally lower concentrations and lower levels resulting in marginally higher concentrations.

Figure 3-30
Projected Release Salinity* Concentration (mg/L) from Glen Canyon Dam Over the 5-Year Simulation Period



Source: USGS 2023a
*Salinity is the measure of the amount of dissolved salt in water, where TDS measures all dissolved solids in a water sample, and it is a similar constituent as it estimates the level of salt within a water sample. TDS was used in the CE-QUAL-W2 model as a proxy for salinity.

Action Alternative 1

Under Action Alternative 1, salinity concentrations in waters released from Glen Canyon Dam would not exceed 723 mg/L, which is the numeric salinity criteria for Hoover Dam as seen in **Figure 3-29**. While Glen Canyon Dam releases are related to the salinity concentrations at Lake Mead and in the waters below Hoover Dam, these modeling results do not represent Hoover Dam release concentrations.

Figure 3-30 further illustrates the trend between Lake Powell elevations and salinity concentrations with higher lake levels resulting in marginally lower concentrations and lower levels resulting in marginally higher concentrations.

Action Alternative 2

Under Action Alternative 2, salinity concentrations in waters released from Glen Canyon Dam would not exceed 723 mg/L, which is the numeric salinity criteria for Hoover Dam as seen in **Figure 3-29**. While Glen Canyon Dam releases are related to the salinity concentrations at Lake Mead and in the waters below Hoover Dam, these modeling results do not represent Hoover Dam release concentrations.

The CE-QUAL-W2 results for Action Alternative 2 also illustrated a general trend between Lake Powell elevation and salinity concentrations. Generally, when lake elevations were high (trace 1992 100 percent ESP), salinity releases were lowest. Conversely, lake elevations at 3,500 feet or lower resulted in high projected salinity concentrations as seen in **Figure 3-29**. **Figure 3-30** further illustrates the trend between Lake Powell elevations and salinity concentrations with higher lake levels resulting in marginally lower concentrations and lower levels resulting in marginally higher concentrations.

Cumulative Effects

If one of the Glen Canyon Dam/Smallmouth Bass flow options were implemented, Reclamation would change how and when releases from Glen Canyon Dam took place. Each of these flow options includes releasing water through the river outlet works, which are lower than the penstocks where water is typically released when hydropower is generated. The difference in salinity between the penstocks and river outlet works is typically negligible during turnover; however, the salinity concentrations at the two elevations are highly variable and they can be as high as 300 mg/L, which can increase the concentrations of salinity releases under certain conditions.

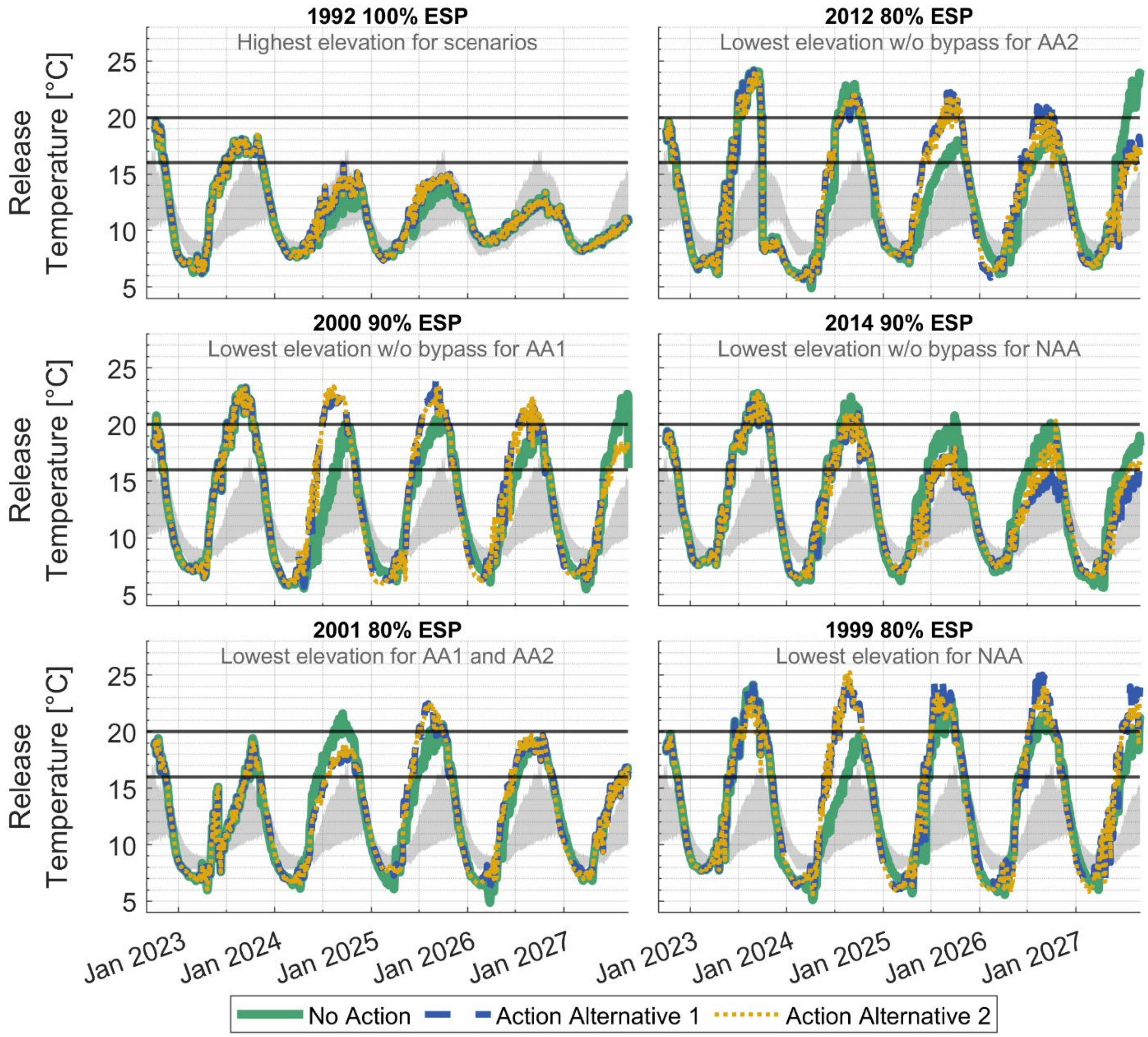
Issue 2: How would elevation protection and low-flow conditions affect temperature within each reach?

Summary

As seen in **Figure 3-31**, projected temperature releases varied greatly among different scenarios. (For a description of the six traces chosen, see the *Methodology* section.) A key determinant of Glen Canyon Dam release temperatures is the elevation of the reservoir relative to where water is being released, either from the penstocks, which is 3,490 feet, or from the river outlet works, which is 3,370 feet.

As seen in the CE-QUAL-W2 model results for Glen Canyon Dam releases in **Figure 3-31**, warmest temperatures were observed in trace 1999 80 percent ESP for the action alternatives, where pool elevation hovered near 3,500 feet just above power pool and released from the penstocks from 2023-2026. Conversely, under the No Action Alternative, the selected traces show a cooling over time due to water being released from colder hypolimnetic waters adjacent to the river outlet works. This is due to elevations dropping below minimum power pool where releases through the river outlet works are necessary. Release temperatures were coldest when reservoir elevations were highest under all alternatives. This last point is critical to consider as the No Action Alternative may result in lower temperatures from 2023 through 2026, but under the No Action Alternative, Lake Powell is much more likely to reach dead pool, which is 3,370 feet. If Lake Powell were to reach dead pool, it would lead to a large increase in temperature.

Figure 3-31
Projected Release Temperatures from Glen Canyon Dam Over the 5-Year Simulation Period for Each Selected Trace and Management Scenario*



Source: USGS 2023a

*Hourly projections from the model were averaged to daily values for illustrative purposes. Horizontal black lines represent 16 °C and 20 °C temperature thresholds. The grey shaded area represents historical daily average temperatures within the 10th and 90th percentiles from 2010 to present.

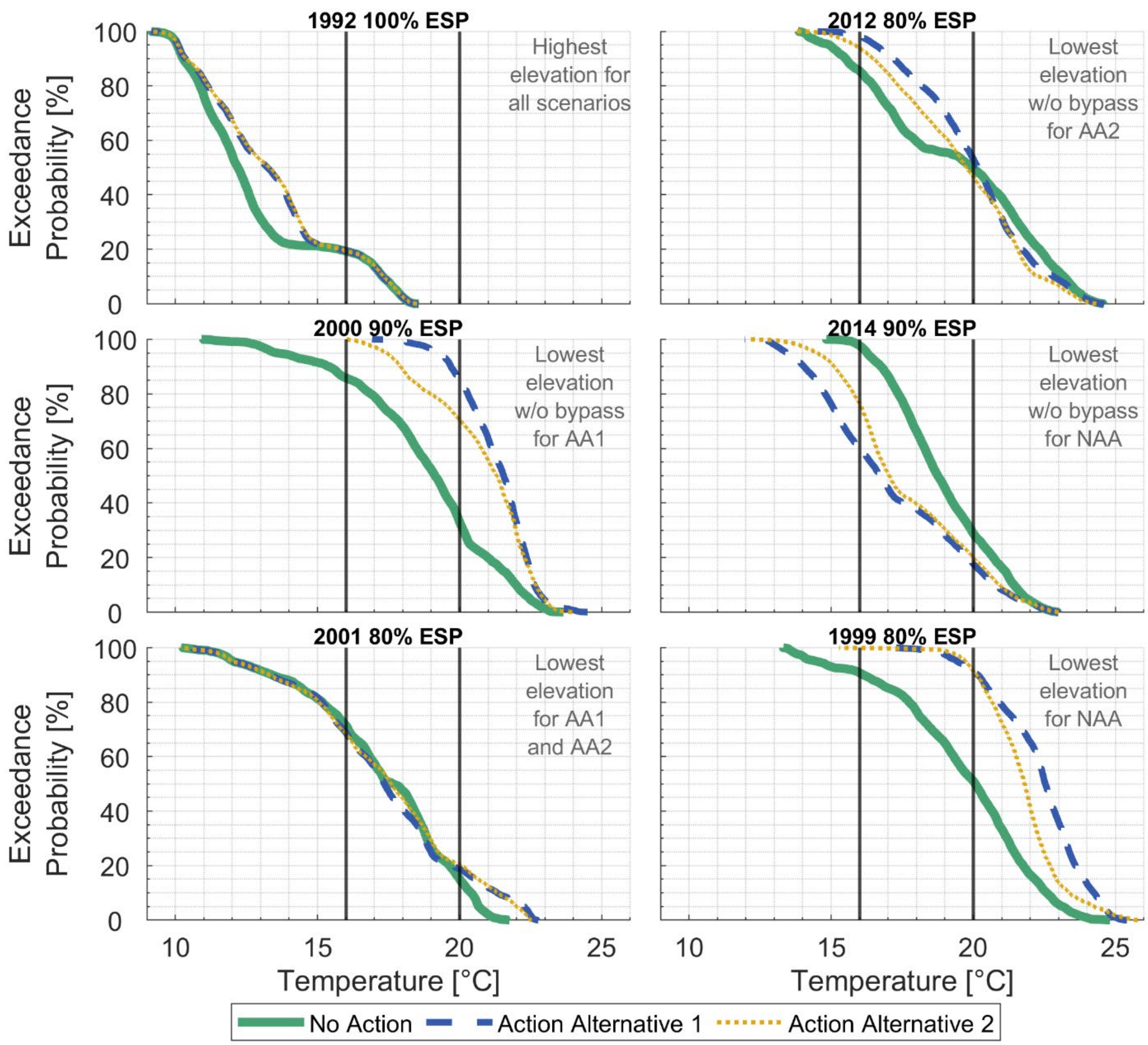
As seen in **Figure 3-32**, the temperature of Lake Powell releases was evaluated based on important temperature thresholds for smallmouth bass and rainbow trout. Smallmouth bass are a concern because the Service's 2018 species status assessment listed this invasive predator as one of the biggest threats to the federally listed humpback chub in the Grand Canyon. When temperatures exceed 16°C, the likelihood that smallmouth bass and other warmwater nonnatives increase in abundance is much higher, while when temperatures exceed 20°C for longer periods of time it is expected to negatively impact salmonids. See **Section 3.13** for more information. In the six traces modeled, the highest probability of release temperature exceeding 16°C was 98 percent for the No Action Alternative in trace 2014 and 90 percent and 100 percent for both action alternatives in traces 2000 90 percent ESP and 1999 80 percent. In the six traces modeled, the highest probability of release temperatures exceeding the 20°C threshold was 51 percent for the No Action Alternative under trace 1999 80 percent ESP, 92 percent for Action Alternative 1 in trace 1999 80 percent ESP, and 91 percent for Action Alternative 2 in trace 1999 80 percent ESP. Release temperatures are strongly tied to where water would be released from which impacted the probability of the No Action Alternative as releases from the river outlet works would be necessary.

Generally, there is good agreement between release temperature projections from the Small Mouth Bass and CE-QUAL-W2 Lake Powell models among all selected traces and management alternatives (**Figure 3-33**). The Small Mouth Bass and CE-QUAL-W2 models had the best agreement in trace 2014 90 percent ESP for both the No Action Alternative and Action Alternative 1 and trace 1992 100 percent ESP for Action Alternative 2 based on reported RMSE values. There is also good model agreement for trace 1999 80 percent ESP under Action Alternative 1 and Action Alternative 2 based on R2 values, both of which had similar Lake Powell elevations, both hovering around 3,500 feet over the 5-year simulation period. The greatest disagreement between models occurred in traces that drop below power pool, especially under the No Action Alternative where 4 of the 6 traces were below power pool for most of the 5-year simulation period.

In examining the full ensemble of hydrologic traces generated by CRMMS using the smallmouth bass model, Action Alternative 1 and Action Alternative 2 would lead to slightly fewer days above 16°C and 20°C on average when compared to the No Action Alternative (**Figure 3-34** and **Figure 3-35**).

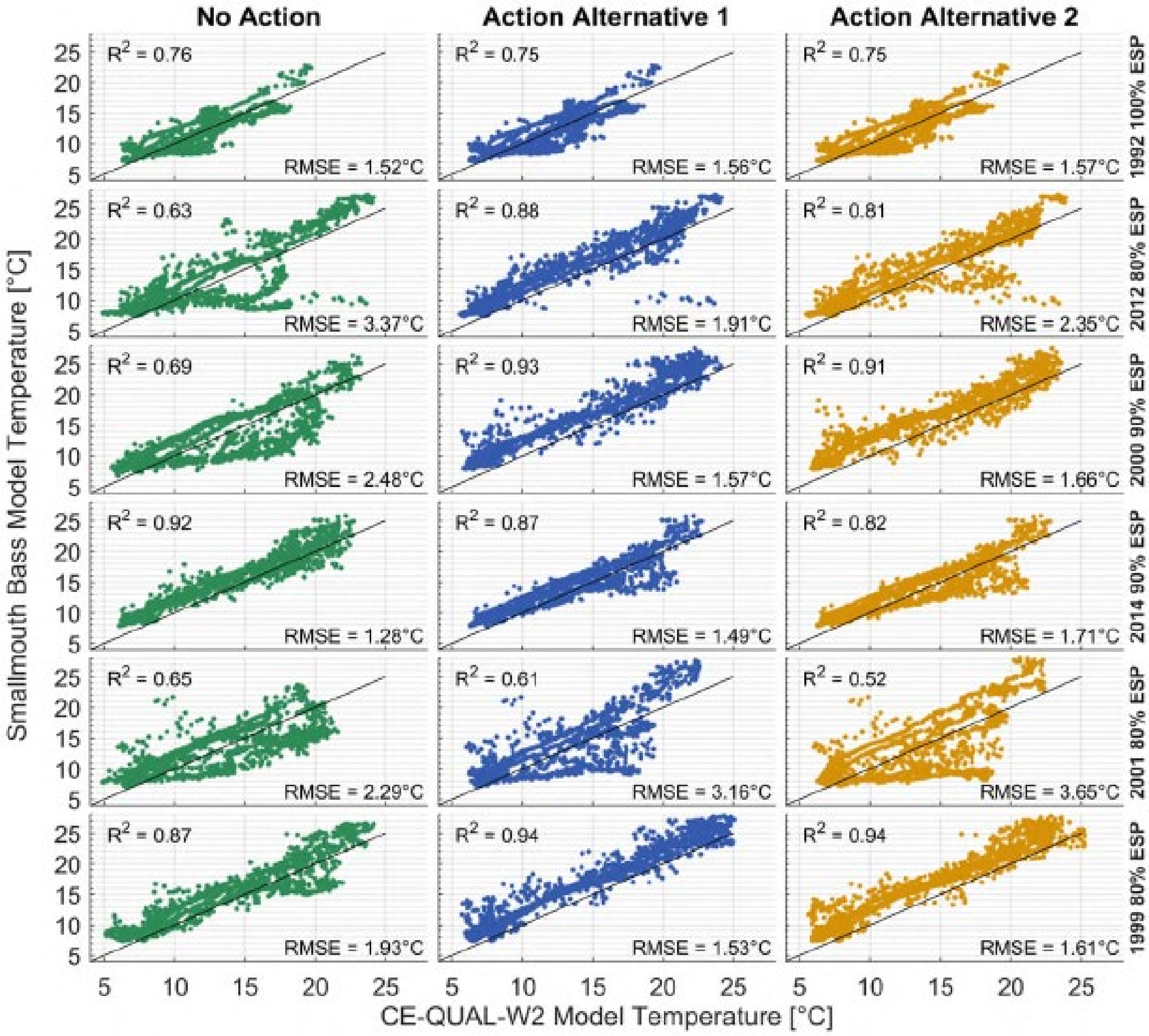
Glen Canyon Dam release temperatures are related to Hoover Dam release temperatures, but this analysis cannot speak to the release temperatures of Hoover Dam without more modeling.

Figure 3-32
Percent Probability of Summertime (July, August, and September) Release Temperatures Exceeding Temperature Thresholds from Glen Canyon Dam Over the 5-Year Simulation Period for Each Selected Trace and Management Scenario



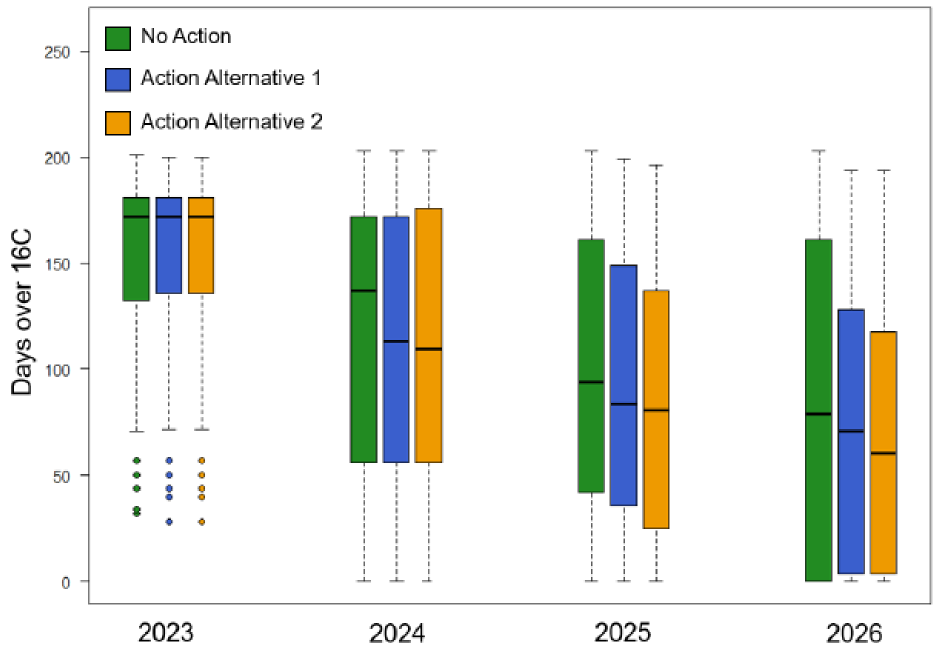
Source: USGS 2023a

Figure 3-33
Scatter Plots Comparing CE-QUAL-W2 and Small Mouth Bass Model Daily Average Release Temperature Projections for Each Selected Trace*



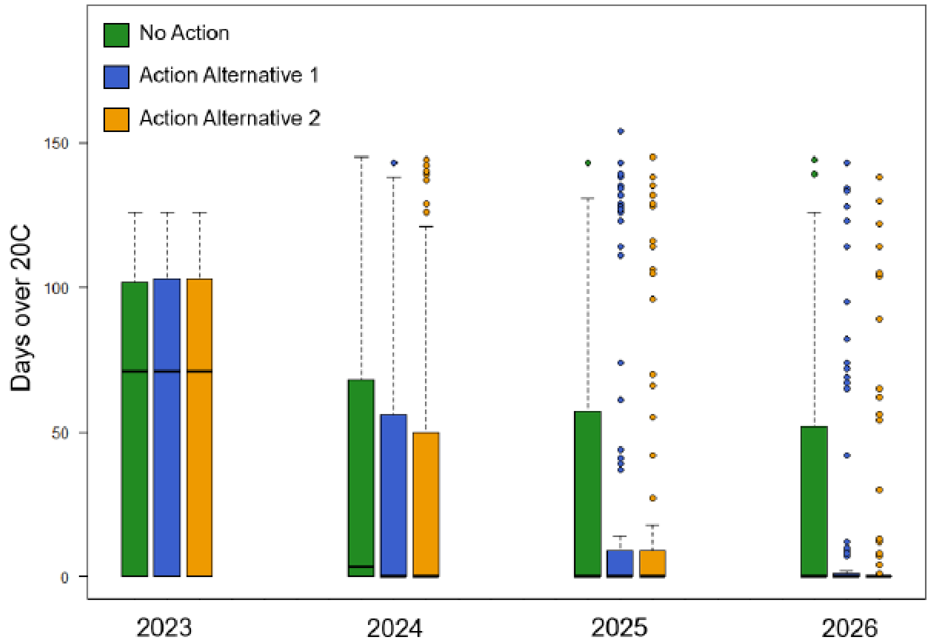
Source: USGS 2023a
*Trace names are shown on the right-hand side of each row of plots. The diagonal black lines indicate a 1:1 relationship.

Figure 3-34
Box Plots Showing the Number of Days with an Average Glen Canyon Dam Release Temperature over 16 °C for all CRMMS Traces and each Alternative for Operating Years 2023–2026*



Source: USGS 2023a
* The dark line represents the median, the boxes represent the upper and lower 25 percent quantiles, and the whiskers extended to twice the interquartile range with dots representing traces with more extreme values.

Figure 3-35
Box Plots Showing the Number of Days with an Average Glen Canyon Dam Release Temperature over 20°C for all CRMMS Traces and each Alternative for Operating Years 2023–2026*



Source: USGS 2023a
* The dark line represents the median, the boxes represent the upper and lower 25 percent quantiles, and the whiskers extended to twice the interquartile range with dots representing traces with more extreme values.

No Action Alternative

As seen in the CE-QUAL-W2 model results for Glen Canyon Dam releases in **Figure 3-31**, water temperature releases were high in trace 1999 80 percent ESP when lake elevations were just above power pool in July 2023 and after elevations dropped closer to the bypass elevation of 3,370 feet in July 2025 and subsequent years. The coldest release temperatures occurred when reservoir elevations were the highest.

In the six traces examined using CE-QUAL-W2, for the No Action Alternative, trace 2014 90 percent ESP had the highest probability of dam releases exceeding the 16°C threshold with a 98 percent probability of occurring. The probability of exceeding the 20°C threshold under the No Action Alternative was 51 percent in trace 1999 80 percent ESP. Release temperatures are strongly linked to the elevation of Lake Powell relative to where the water is being released, which affects the probability of exceeding specific temperature thresholds.

Release temperatures were coldest when reservoir elevations were highest. This last point is critical to consider as the No Action Alternative may result in lower temperatures. However, under the No Action Alternative, Lake Powell is much more likely to reach dead pool. If Lake Powell were to reach dead pool, 3,370 feet, it would lead to a large increase in temperatures.

Action Alternative 1

Action Alternative 1 scenarios resulted in higher temperatures relative to the No Action Alternative where pool elevation hovered near 3,500 feet just above power pool and water would be released from the penstocks. As seen in **Figure 3-31**, the warmest water release temperatures were observed in trace 1999 80 percent ESP where pool elevation hovered around 3,500 feet from 2023-2026. The minimum elevation trace, 2001 80 percent ESP, for Action Alternative 1 had relatively lower water temperatures compared to the 1999 80 percent ESP trace.

The coldest release temperatures occurred when reservoir elevations were the highest.

For Action Alternative 1, in the six traces examined using CE-QUAL-W2, 2000 90 percent ESP and 1999 80 percent ESP traces had the highest probability of release temperatures exceeding 16°C at 100 percent. The probability of exceeding the 20°C threshold under Action Alternative 1 was 92 percent in trace 1999 80 percent ESP.

Action Alternative 2

Action Alternative 2 scenarios resulted in higher temperatures relative to the No Action Alternative where pool elevation hovered near 3500 feet just above power pool and water would be released from the penstocks. As seen in **Figure 3-31**, the warmest water release temperatures were observed in trace 1999 80 percent ESP where pool elevation hovered around 3,500 feet from 2023-2026. The minimum elevation trace, 2001 80 percent ESP, for Action Alternative 2 had relatively lower water temperatures compared to the 1999 80 percent ESP trace. The coldest release temperatures occurred when reservoir elevations were the highest.

For Action Alternative 2, in the six traces examined using CE-QUAL-W2, 2000 90 percent ESP and 1999 80 percent ESP traces had the highest probability of release temperatures exceeding 16°C at 100 percent. The probability of exceeding the 20°C threshold under Action Alternative 2 was 91 percent in trace 1999 80 percent ESP.

Cumulative Effects

If one of the Glen Canyon Dam/Smallmouth Bass flow options were implemented, Reclamation would change how and when releases from Glen Canyon Dam would take place. Each of these flow options includes releasing water through the river outlet works, which are lower than the penstocks where water is typically released when hydropower is generated. Reclamation would redirect certain release volumes from the higher hydropower-generating penstocks to the lower river outlet works. Releases from the lower river outlet works would be cooler in temperature; therefore, no additive cumulative effect would occur from Glen Canyon Dam flow options.

Issue 3: How would elevation protection and low-flow conditions affect sediment within each reach?

Summary

Under all alternatives, HFEs in the reach between Lake Powell and Lake Mead (in Marble and Grand Canyons) would not be implemented when Lake Powell elevations are below the Protection Level (3,500 feet). Under all alternatives and given the current LTEMP protocols, the modeling results indicate that spring HFEs would only be triggered for approximately 15 percent of the time and fall HFEs would be triggered approximately 70 percent of the time, each year, between 2024 and 2026 (see **Figure 3-36**). Net erosion of sandbars would occur, and sandbar building would decrease, if HFEs cannot be implemented (see **Figure 3-37**). However, Action Alternatives 1 and 2 would reduce the potential of elevations below the Protection Level, and, therefore, would increase the probability of HFE implementation compared with the No Action Alternative.

In **Figure 3-36**, the blue (leftmost) "sediment-triggered" bars represent the probability that there is enough sediment to implement an HFE of the indicated duration, without causing the sand mass balance to become negative by the end of the sediment accounting window. The orange (middle) "volume constraint" bars represent the probability of implementing an HFE of the indicated duration (with the volume of water allocated in the implementation month) while also maintaining LTEMP-required minimum daily LTEMP releases (see **Table 3-26**). The yellow (rightmost) bars represent the probability an HFE of the indicated duration could be implemented given the volume constraint combined with the Lake Powell Protection Level (greater than 3,500 feet) constraint. Under the last scenario, even when sufficient monthly volume is available, Lake Powell's elevation could prevent HFE implementation. Similarly, both volume constraint scenarios prevent the implementation of HFEs of the duration that are triggered following the LTEMP protocol (a 96-hour HFE).

Table 3-26
Monthly Minimum Volume Constraints for HFEs

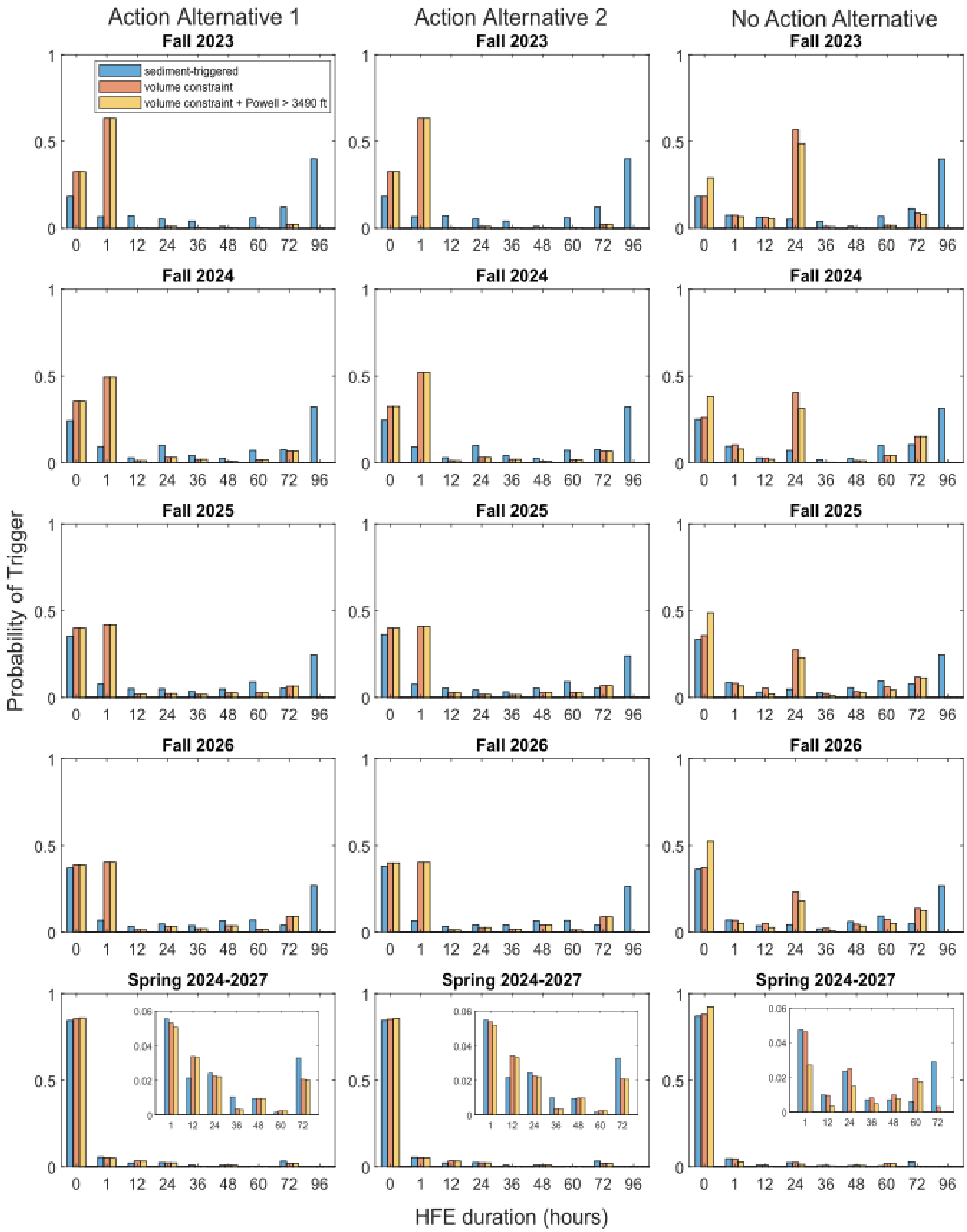
HFE Duration	0-hour	1-hour	12-hour	24-hour	36-hour	48-hour	60-hour	72-hour	96-hour
Volume (af)[1]	394,210	426,800	456,200	490,090	522,400	556,300	588,600	622,500	688,700

Source: Salter and Grams 2023
[1]Total releases less than these volumes are not possible without decreasing flows below the LTEMP-required minimum daily (8,000 cfs) and nightly (5,000 cfs) releases.

At a 0-hour duration, an HFE would not occur. The volume constraint and volume constraint combined with the Lake Powell Protection Level constraint would cause HFEs of longer duration (12 to 96 hours) to be substituted with one-hour HFEs (see **Figure 3-36**). Based on the Mueller and Grams (2021) sandbar model, a one-hour HFE is projected to be less than 5 percent as effective as a 96-hour HFE. Those HFEs with durations shorter than approximately 60 hours have never been tested and they would be of unknown effectiveness. Short-duration HFEs were included as an option in the LTEMP to be implemented when there was insufficient sediment available for longer duration HFEs (Reclamation and NPS 2016).

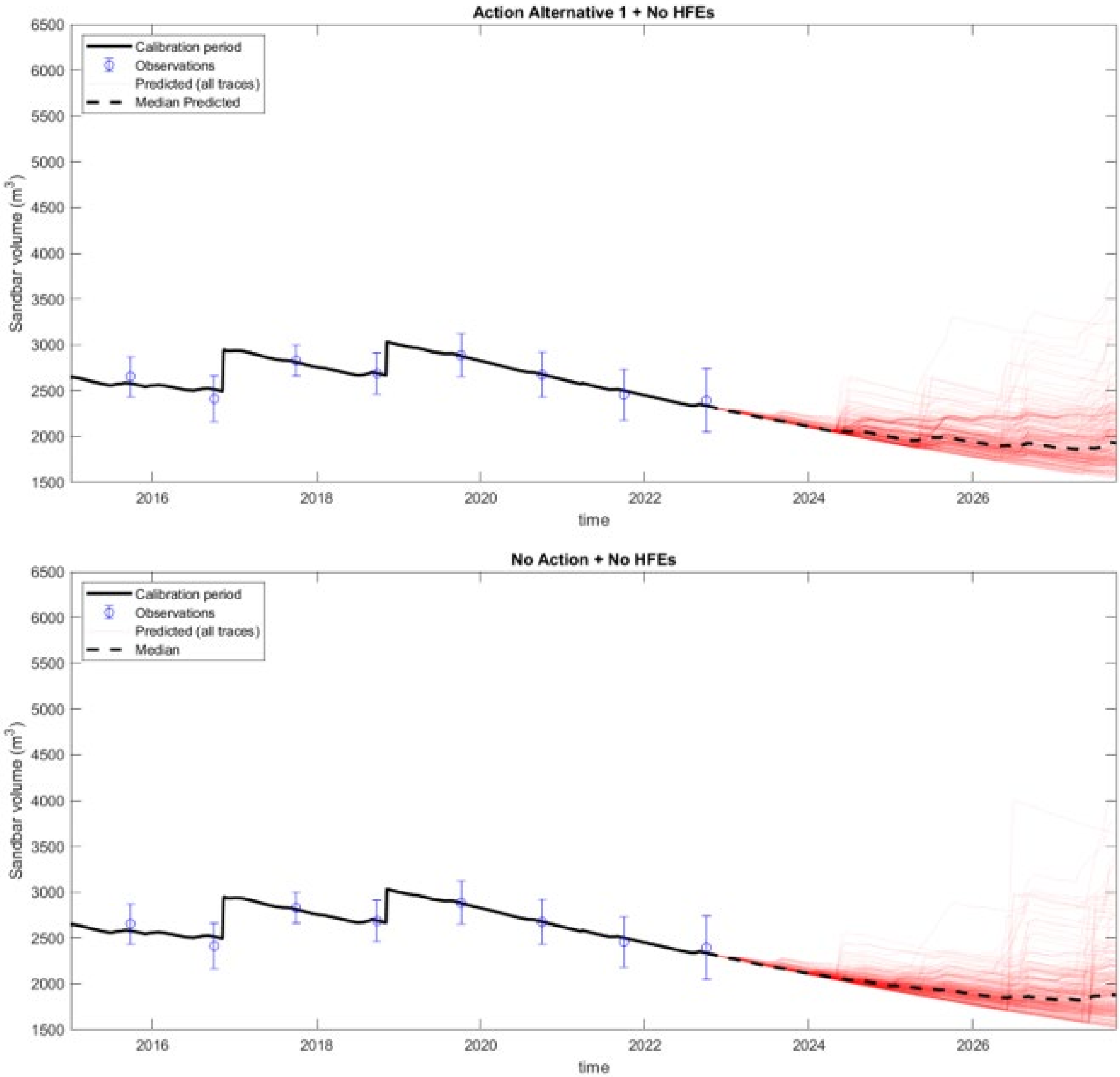
Sediment dredging projects in the reach below the Hoover Dam that ensure water delivery to downstream users would continue under all alternatives.

Figure 3-36
Probabilities of HFE Trigger under LTEMP Sediment Accounting Windows



Source: Salter and Grams 2023

Figure 3-37
Observed and Predicated Sandbar Volume with no HFE Implementation



Source: Salter and Grams 2023

No Action Alternative

Under the No Action Alternative, low-flow conditions would continue to affect the sediment mass balance by limiting sand deposition in eddies and on sandbars in the reach between Lake Powell and Lake Mead. If Lake Powell drops below 3,500 feet, HFEs are infeasible (Salter and Grams 2023). Sand deposition in the Marble and Grand Canyons would be insufficient to build sandbars. In addition, sandbars would progressively erode between current conditions and through 2026 (see **Figure 3-37**).

Under the No Action Alternative, current modeling demonstrates that spring HFEs would only be triggered for approximately 15 percent of the time and fall HFEs would be triggered approximately 70 percent of the time, each year, between 2024 and 2026 under the LTEMP protocols (see **Figure 3-36**). These results are consistent with the modeling analyses for LTEMP, which anticipated that fall HFEs would be triggered in about 77 percent of the years and spring HFEs would be triggered in about 26 percent of the years, using different hydrology inputs and slightly different sediment assumptions (Reclamation and NPS 2016). It should be noted that there has not been an HFE since 2018. If neither spring or fall HFEs can be implemented, net erosion of sandbars would continue, and existing sandbars would erode (Salter and Grams 2023).

Sediment dredging projects in the reach below Hoover Dam that ensure water delivery to downstream users would continue under the No Action Alternative.

Action Alternative 1

According to the modeling results, fall and spring HFEs under Action Alternative 1 would be triggered for approximately the same occurrence (15 percent of the time for spring HFEs and 70 percent of the time for fall HFEs) as the No Action Alternative (see **Figure 3-36**). Impacts on sediment in the reach between Lake Powell and Lake Mead when Lake Powell elevations are below the Protection Level (3,500 feet) would be the same as described under the No Action Alternative. However, the potential for the elevation to drop below this level would decrease under Action Alternative 1. This would increase the potential for HFE implementation compared with the No Action Alternative. If neither spring or fall HFEs can be implemented, net erosion of sandbars would continue, and existing sandbars would erode (Salter and Grams 2023).

Sediment accumulation in the reach downstream of the Hoover Dam would continue, as described under the No Action Alternative, and so would the need for sediment dredging projects.

Action Alternative 2

There are negligible differences between the modeling results for Action Alternatives 1 and 2 (see **Figure 3-36**). Therefore, impacts on sediment in the reach between Lake Powell and Lake Mead would be the same as those described under Action Alternative 1.

Sediment accumulation in the reach downstream of the Hoover Dam would continue, as described under the No Action Alternative, and so would the need for sediment dredging projects.

Cumulative Effects

If one of the Glen Canyon Dam/Smallmouth Bass flow options were implemented this would change how and when releases from Glen Canyon Dam occur. Each of these flow options includes releasing water through the river outlet works, which are lower than the penstocks (the place where water is typically released when hydropower is generated). Combined with the HFE implementation effects in this analysis, if the release volumes are 20,000 cfs or greater, the monthly flow constraint would have a greater influence on the probability of triggering an HFE. The probability would likely decrease. Action Alternatives 1 and 2 would reduce this cumulative effect, compared with the No Action Alternative, because these alternatives would reduce the potential for Lake Powell elevation dropping below the Protection Level. If an HFE is triggered and the dam releases are implemented at the duration and magnitude consistent with the LTEMP protocol, sandbar building would occur.

Issue 4: How would elevation protection and low-flow conditions affect nutrients and algae within each reach?

Summary

As Action Alternative 1 and 2 would lead to slightly higher temperatures, these may provide more opportunities for algal growth. Declining water levels in Lake Powell could promote cyanobacteria blooms, but this remains to be studied (Yang et al. 2016). However, while the No Action Alternative may result in lower temperatures, under the No Action Alternative, Lake Powell is much more likely to reach dead pool, which is 3,370 feet. If Lake Powell were to reach dead pool, temperatures would be expected to rise. This increase in temperature would create more opportunities for algal growth.

Additionally, an increased probability of low DO events would create more bioavailable phosphorus, which may also provide more opportunities for algal growth under Action Alternatives 1 and 2 as seen in **Figure 3-38**. DO is discussed in more detail under *Issue 5*.

Lower flows under Action Alternatives 1 and 2 and decreased dilution capacity under all alternatives could result in greater concentrations of nitrogen and phosphorus; however, quantified water quality impacts related to dilution capacity are not available; therefore, it is difficult to project the quantified water quality impacts based on dilution capacity.

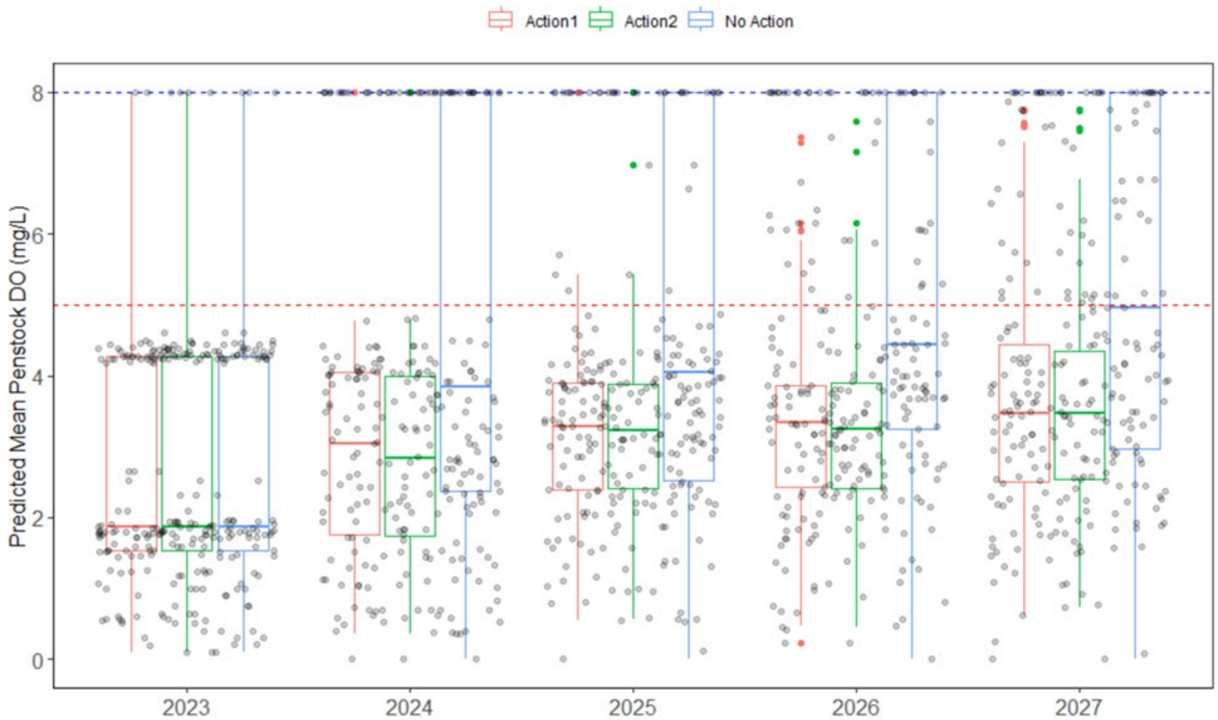
No Action Alternative

Under the No Action Alternative, Glen Canyon Dam releases would have slightly cooler temperatures than Action Alternatives 1 or 2, as discussed under *Issue 2*.

Decreased dilution capacity could result in greater concentrations of nitrogen and phosphorus; however, quantified water quality impacts related to dilution capacity are not available; therefore, it is difficult to project the quantified water quality impacts based on dilution capacity.

Additionally, with lower reservoir levels, it is possible that phosphorus concentrations in the hypolimnion, where water would be released, could be elevated depending on seasonality and reservoir nutrient cycling. Higher temperatures downstream and decreased concentrative power from lower water volumes could result in more opportunities for algal growth. Bypass-only scenarios would likely result in more algal growth due to steady flows versus load following flows (Deemer 2023).

Figure 3-38
Projections of mean August-October DO concentrations in Glen Canyon Dam outflows for each projection year under Action Alternative 1, Action Alternative 2, and No Action Alternative



Source: USGS 2023b

Under the No Action Alternative, low DO events occur in 68 percent of years as shown in **Figure 3-38**. This occurs in the late summer and early fall, which could lead to more bioavailable phosphorus and opportunities for algal growth.

Action Alternative 1

A key determinant of release temperature is Lake Powell's reservoir elevation relative to where water is being released, either from the penstocks at 3,490 feet or from the river outlet works at 3,370 feet. Due to water levels being held just above power pool for extended periods of time in the Action Alternative 1, these scenarios resulted in higher temperatures relative to the No Action Alternative.

Lower flows and decreased dilution capacity could result in greater concentrations of nitrogen and phosphorus; however, quantified water quality impacts related to dilution capacity are not available; therefore, it is difficult to project the quantified water quality impacts based on dilution capacity.

Additionally, phosphorus concentrations increase down the water column where releases would be made. Higher temperatures downstream and decreased concentrative power from lower water volumes could result in algal blooms and more opportunities for algal growth.

Under Action Alternative 1, low DO events would occur in 91 percent of years as shown in **Figure 3-38**. There is an increased probability of decreased DO concentrations in the late summer and early fall, which could lead to more bioavailable phosphorus and opportunities for algal growth.

Action Alternative 2

A key determinant of release temperature is Lake Powell's reservoir elevation relative to where water is being released, either from the penstocks at 3,490 feet or from the river outlet works at 3,370 feet. Due to water levels being held just above power pool for extended periods of time in the Action Alternative 2, these scenarios resulted in higher temperatures relative to the No Action Alternative.

Lower flows and decreased dilution capacity could result in greater concentrations of nitrogen and phosphorus; however, quantified water quality impacts related to dilution capacity are not available; therefore, it is difficult to project the quantified water quality impacts based on dilution capacity.

Additionally, phosphorus concentrations increase down the water column where releases would be made. Higher temperatures downstream and decreased concentrative power from lower water volumes could result in algal blooms and more opportunities for algal growth.

Under Action Alternative 2, low DO events would occur 91 percent of years as shown in **Figure 3-38**. There is an increased probability of decreased DO concentrations in the late summer and early fall, which could lead to more bioavailable phosphorus and opportunities for algal growth.

Cumulative Effects

If one of the Glen Canyon Dam/Smallmouth Bass flow options were implemented, Reclamation would change how and when releases from Glen Canyon Dam took place. Each of these flow options includes releasing water through the river outlet works, which are lower than the penstocks where water is typically released when hydropower is generated. The resulting releases from lower in the water column would be higher in total phosphorus, which may improve food web conditions given the food limited nature of the ecosystem. The phosphorus concentrations at depth are not markedly greater than some phosphorus concentrations that have already been released under higher lake levels.

Issue 5: How would elevation protection and low-flow conditions affect DO within each reach?

Summary

Low DO events typically occur in zones of Glen Canyon Dam's metalimnion [13] in September or early October but have been observed as early as August in response to large spring inflows, such as from snowmelt.

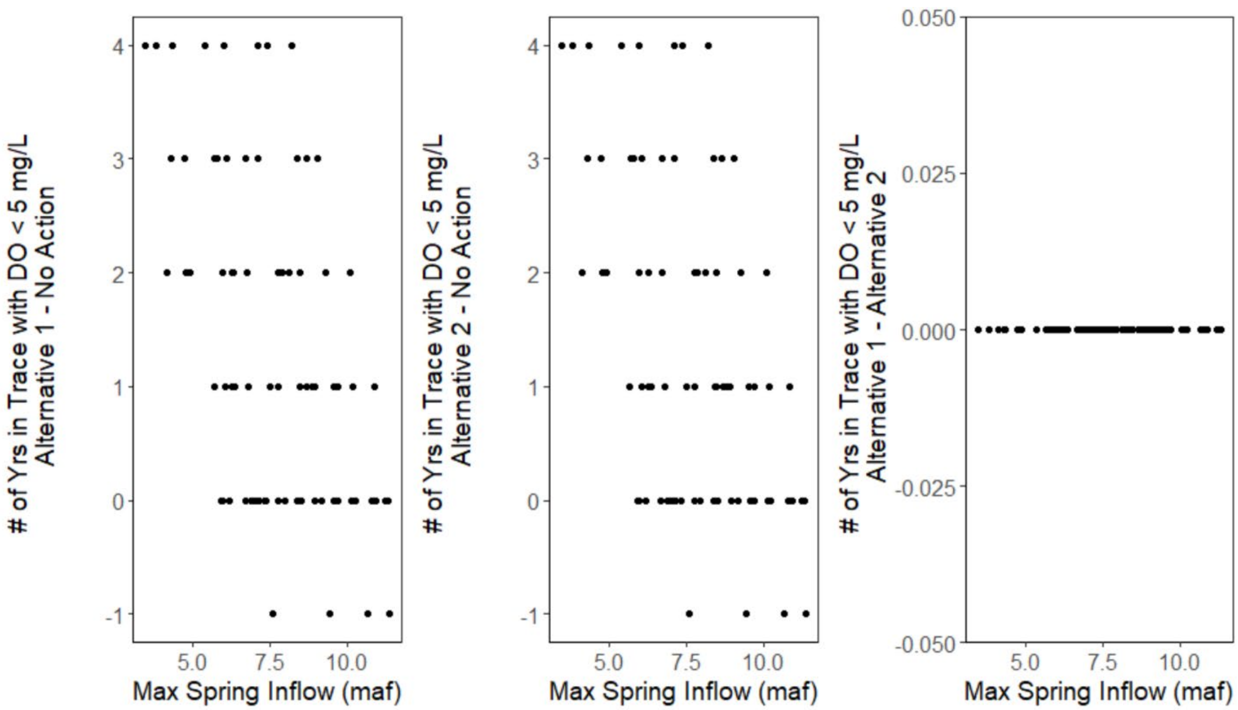
As seen in **Figure 3-38**, across all alternatives, mean August to October DO in Lake Powell is projected to drop below 5 mg/L in 83 percent of traces. The probability of low DO events occurring in the tailwater would be more likely under the action alternatives than the No Action Alternative. This difference increases during later years due to the use of the river outlet works

[13] The metalimnion is the middle layer in a thermally stratified lake or reservoir.

under the No Action Alternative, which provides aeration. **Figure 3-38** shows a dashed red line for 5mg/L, which is the threshold below which oxygen concentrations are stressful to trout (see **Section 3.13**, Biological Resources for more information), and a dashed blue line for 8mg/L, which is the concentration modeled for bypass release . Each point represents 1 year for a total of 90 points per box whisker (30 historical reconstructions x 100 percent, 90 percent, and 80 percent).

As seen in **Figure 3-39**, there were no differences in the modeled probability of low DO events between the action alternatives.

Figure 3-39
Differences in the Number of Years Within Each Trace Likely to Have a Low DO Event As a Function of Maximum Spring Inflow in the Trace



Source: USGS 2023b

No Action Alternative

Under the No Action Alternative, Glen Canyon Dam releases mean August-October DO levels would drop below 5 mg/L in 68 percent of years. DO also has an increasing trend over time on an August-October time period as release through the river outlet works is predicted to increases under this alternative, especially in later years. **Figure 3-38** shows the modeled mean August-October DO concentrations in Glen Canyon Dam outflows for each model year under the No Action Alternative in blue.

Action Alternative 1

Under Action Alternative 1, Glen Canyon Dam releases mean August-October DO levels would drop below 5 mg/L in 91 percent of years. **Figure 3-38** shows the projections of mean August-

October DO concentrations in Glen Canyon Dam releases for each projection year under Action Alternative 1 in pink.

Under Action Alternative 1, it would be more likely that the tailwater[14] below Glen Canyon Dam would have more low DO events than under the No Action Alternative because of the No Action Alternative's increased use of the river outlet works which aerate the releases.

Action Alternative 2

Under Action Alternative 2, Glen Canyon Dam releases mean August-October DO levels would drop below 5 mg/L in 91 percent of years. **Figure 3-38** shows the projections of mean August-October DO concentrations in Glen Canyon Dam releases for each projection year under Action Alternative 2 in green.

Under Action Alternative 2, it would be more likely that the tailwater below Glen Canyon Dam would have more low DO events than under the No Action Alternative because of the No Action Alternative's increased use of the river outlet works which aerate the releases.

Cumulative Effects

If one of the Glen Canyon Dam/Smallmouth Bass flow options were implemented, Reclamation would change how and when releases from Glen Canyon Dam took place. Each of these flow options includes releasing water through the river outlet works which are lower than the penstocks where water is typically released when hydropower is generated. However, passage through the river outlet works would also aerate the water so this likely would not lead to a cumulative effect on DO.

Issue 6: How would elevation protection and low-flow conditions affect metals within each reach?

Summary

As elevations decrease, the dilution capacity of Lake Powell and Lake Mead would also decrease, but they would not be expected to result in any significant decrease in dilution capacity or increase in concentrations of metals of concern. Quantitative metal modeling results were not available at the time of this report, therefore only a qualitative discussion is included. Without more specific modeling, it is difficult to project the quantified water quality impacts and alternatives cannot be compared.

No Action Alternative

Even with the projected drawdown, it is unlikely that the No Action Alternative would significantly increase the concentration of metals because dilution capacity is not likely to reduce significantly. However, without more specific modeling, it is difficult to project the quantified water quality impacts.

Under the No Action Alternative, Lake Powell is much more likely to reach dead pool, which is 3,370 feet. (See **Section 3.6**, Hydrologic Resources, for more information.) This may affect metals'

[14] Tailwater is the water below the reservoir that would be more similar to reservoir waters than downstream waters.

concentrations as elevations would continue to decrease, but impacts cannot be assessed without quantified impacts.

Action Alternative 1

Under Action Alternative 1, the likelihood of drawing down below 1,000 feet would be small, similar to what was originally analyzed in the 2007 FEIS. Therefore, the projected elevations and corresponding changes in dilution capacity would not be expected to result in a significant reduction in dilution capacity or any significant increase in concentrations of metals of concern. However, without more specific modeling, it is difficult to project the quantified water quality impacts.

Action Alternative 2

Under Action Alternative 2, shortage reductions in excess of previous commitments would be distributed as a percentage reduction based on 2021 consumptive use. Therefore, the likelihood of drawing down below 1,000 feet would be small, like what was originally analyzed in the 2007 FEIS. Therefore, the projected elevations and corresponding changes in dilution capacity would not be expected to result in a significant reduction in dilution capacity and any significant increase in concentrations of metals of concern. However, without more specific modeling, it is difficult to project the quantified water quality impacts.

Cumulative Effects

If one of the Glen Canyon Dam/Smallmouth Bass flow options were implemented, Reclamation would change how and when releases from Glen Canyon Dam took place. This would not result in any changes to monthly or annual release volumes, but it would change how and when those releases took place. Therefore, there is not an expected change to elevation that would impact metals' concentrations.

3.9 Air Quality

3.9.1 Affected Environment

To supplement the 2007 FEIS (Reclamation 2007), this section provides a brief summary of a more comprehensive description of the affected environment in the 2007 FEIS, supplementing, as necessary, to include changes that have occurred since 2007. For additional information, see the 2007 FEIS (Reclamation 2007) and the 2016 LTEMP FEIS (Reclamation and NPS 2016), which are incorporated by reference.

The primary air quality issue is fugitive emissions (dust) generated from shorelines exposed due to reductions in Lake Powell and Lake Mead elevations, affecting particulate levels regionally, including GCNP. The potential for fugitive dust emissions is limited by the extent of the area containing fine sediment having the potential to generate dust.

The other air quality issue, which was not addressed in the 2007 FEIS, is GHG emissions. The alternatives analyzed may indirectly affect air quality by potentially changing the degree to which electricity demand is met within the region, with either non-emissive hydropower, wind, or solar powerplants, or emission-producing powerplants, such as fossil fuel-fired powerplants that can directly affect air quality and related resources. These air quality changes can also affect GHG emissions that can influence climate change. Therefore, dam operations can affect air quality and GHG emissions within the 11-state Western Interconnection region, which includes Arizona, California, Colorado, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington, and Wyoming. This is because hydropower generation offsets generation from other generating facilities (that is, coal-fired and natural gas-fired facilities) in the Western Interconnection. The 2016 LTEMP (Reclamation and NPS 2016, Table 3.15-3) presents criteria pollutant, volatile organic compounds, and GHG emissions over the 11-state area within the Western Interconnection.

Federal Air Quality Requirements

The federal air quality requirements described in the 2007 FEIS are unchanged. The determination that no major stationary sources are being proposed by the proposed alternatives and, therefore, the statutory provisions are not applicable, is also unchanged. However, these standards still provide thresholds from which to evaluate potential effects on ambient air quality. Lake Powell, Lake Mead, and GCNP are still designated as Prevention of Significant Deterioration (PSD) Class II, Class II, and Class I, respectively. The PSD air quality constraints are most stringent in Class I areas and are progressively less stringent in the Class II and Class III areas, and have associated allowable particulate matter (PM) concentration increases over the baseline concentrations.

State and Local Air Quality Requirements

The federal and state National Ambient Air Quality Standards (NAAQS) presented in the 2007 FEIS have been updated as follows:

- NAAQS $PM_{2.5}$ annual standard (primary now 12 $\mu g/m^3$ reduce from 15 $\mu g/m^3$; secondary standard is 15 $\mu g/m^3$).

EPA is currently proposing to retain the current PM_{10} and $PM_{2.5}$ 24-hour standards but is considering revising the primary annual $PM_{2.5}$ standard from its current level of 12.0 $\mu g/m^3$ to within the range of 9.0 to 10.0 $\mu g/m^3$. These PM standards were promulgated to better protect the public from particulate exposures. Additionally, each state must develop an implementation plan describing how it will attain and maintain the NAAQS. Some states have developed more stringent ambient air quality standards for PM_{10} and $PM_{2.5}$, while others have adopted PM standards to meet the previous NAAQS, as follows:

- Nevada, Arizona, and Utah all now have a $PM_{2.5}$ 24-hour standard of 35 $\mu g/m^3$ and the annual PM_{10} standard has been removed; and
- The California $PM_{2.5}$ 24-hour standard has been removed.

Three state and local air quality agencies are responsible for attaining the state and federal standards within the study area: Arizona Department of Environmental Quality; Utah Department of Environmental Quality, Division of Air Quality; and Clark County Air and Environmental Management.

Ambient Air Quality by River Reach

As the 2007 FEIS states, attainment status provides a qualitative characterization of a reach, as compliant with the standards and attainment characterizes the specific pollutant as not a significant concern within the reach. Consequently, characterizing the attainment status in the reaches provides a qualitative assessment of the significance of air pollutant emissions within the reach. The Arizona counties of Mohave, Coconino, Yavapai, and Navajo, and the Utah counties of Washington, Kane, and San Juan are in attainment for all pollutants. Clark County, Nevada—Las Vegas, in particular—is in attainment for all pollutants except 8-hour ozone. The attainment status has improved since the 2007 FEIS, as Clark County's PM_{10} was redesignated from non-attainment to maintenance in November 2014.

While some urban areas (including Las Vegas, North Las Vegas, and Henderson) within Clark County are maintenance areas under the PM_{10} NAAQS, the remaining county, including Lake Mead, is in attainment of the standard. Mohave County, Arizona, adjacent to Lake Mead, is also in attainment of the PM_{10} standard (Reclamation 2000). The Lake Powell and Glen Canyon Dam reach and Lake Mead and Hoover Dam reach are both in a PSD Class II area. As lake levels have decreased since 2007, PM due to dust has likely increased. In 2018, 24-hour PM_{10} levels at Lake Mead reached 116 $\mu g/m^3$, which is about 77 percent of the 150 $\mu g/m^3$ NAAQS. The State of Nevada started a regulatory PM_{10} monitor in Boulder City, Nevada, in 2021. In this first year of monitoring, 24-hour PM_{10} levels exceeded the 24-hour NAAQS at 190 $\mu g/m^3$, which is 127 percent of the standard. These current high levels demonstrate that dust is already a concern for the Lake Mead region; with the decreasing water levels since 2007, additional dust would affect local air quality and public health for both the Lake Powell and Glen Canyon Dam reach and Lake Mead and Hoover Dam reach.

3.9.2 Environmental Consequences

This section analyzes the potential effects of the alternatives on air quality resources. The following issues are addressed:

- Impacts on fugitive dust from changes in shoreline exposure due to changes in lake reservoir elevations
- Impacts on GHGs from changes in hydropower generation due to changes in lake reservoir elevations and releases

Methodology

Similar to the 2007 FEIS, this analysis evaluates the relative difference between the action alternatives and the No Action Alternative. Fugitive emissions can result from exposed sediment on the shorelines of Lake Powell and Lake Mead as a result of fluctuations in the elevations of these reservoirs. The mass of particulates generated per acre of exposed shoreline would vary depending on sediment characteristics and other factors such as saturation, sediment disturbance, wind speeds, and topography.

Both Lake Mead and Lake Powell have potentially experienced increased dust from newly exposed shoreline; however, neither park has current or historical air quality monitoring or modeling data to determine baseline levels. Additionally, any potential heavy metals or other contaminants in exposed sediment has not been determined due to lack of sampling. As lake levels drop and dry out, unvegetated sediments are more likely to become airborne during wind events, causing negative impacts on air quality at localized locations due to blowing dust. Some of these areas may be located at or near heavily visited marinas and beaches. Both parks advocate for deployment of air quality monitoring equipment, sediment testing, and modeling activities to appropriately inform the SEIS implementation activities prior to 2026.

To perform the shoreline exposure portion of the air quality analysis, the NPS used the 10th percentile data for the 80 percent ESP hydrology scenario provided by Reclamation; this shows the ranges for elevations at Lake Powell and Lake Mead (NPS 2023m). In addition, geographic information system (GIS) acreage information was prepared utilizing the United States Geological Survey's (USGS's) 2021 Modified topobathymetric elevation data for Lake Powell, which is a topobathymetric digital elevation model. Topobathymetric data are a merged rendering of both topography (land elevation) and bathymetry (water depth) to provide a single product useful for inundation mapping and a variety of other applications. For a conservative assessment, the lowest extent of the 10th percentile in the 4-year period was utilized to determine the elevation, inundation (acres of water), and acres of exposed shoreline at Lake Powell and Lake Mead. The results of these analyses are used throughout this section.

The way hydropower is generated has not changed since 2007. However, recent drought conditions in the Basin have led to a decrease in hydropower generation since the 2007 FEIS (Reclamation 2021b). The Glen Canyon Powerplant accounts for approximately 75 percent of the Upper Colorado Basin's annual energy production (Reclamation 2007). Despite the improved efficiency since 2007, Glen Canyon Powerplant has still been heavily affected by drought conditions in the Basin, and the powerplant's capacity decreases as the lake elevation drops. As discussed, these reductions of power generation could result in increased GHG emissions due to coal or natural gas supplementing the otherwise non-emissive hydropower energy.

Reclamation, with the assistance of WAPA, conducted a study of the potential effects of the No Action Alternative and action alternatives on electrical power resources of the Colorado River system that included all major facilities. Reclamation's CRMMS helped develop potential releases, reservoir elevations, and power generation from the action alternatives. WAPA's GTMax (modeling was used to further analyze impacts on the Glen Canyon Powerplant. GTMax simulates the dispatch of electric-generating units and the economic trade of energy among utility companies using a network representation of the power grid. Using the changes in megawatt hour for the alternatives and conversion emission factors for coal and natural gas from the US Energy Information Administration (EIA) energy conversion calculator, the estimated metric tons (MT) of carbon dioxide equivalent (CO_2e) were calculated (EIA 2023). The results of these analyses are used throughout this section.

Impact Analysis Area

The impact analysis area for fugitive dust is the same as the analysis area used for the 2007 FEIS, which includes the Glen Canyon to Lake Mead reach because PM generated at the Lake Mead delta may be dispersed into this reach. The impact analysis area is divided into three sections: 1) Lake

Powell and Glen Canyon Dam, 2) Glen Canyon Dam to Lake Mead, and 3) Lake Mead and Hoover Dam.

The analysis area includes every major hydropower facility along the Colorado River, from Lake Powell to the southern international border. Facilities include the Glen Canyon Powerplant, the Hoover Powerplant, the Davis Powerplant, and the Parker Powerplant. Other smaller facilities along the river include Headgate Rock Powerplant, Senator Wash, Siphon Drop, and Pilot Knob. These smaller facilities would not be impacted by the action alternatives and have, therefore, been removed from further analysis.

Given that climate change is a global phenomenon and the effects of GHG emissions are considered cumulative, the GHG impact analysis area would include the aforementioned 11-state Western Interconnection grid and the rest of the United States.

Assumptions

The method for assessing potential fugitive dust emissions from exposed shoreline sediments at Lake Powell and Lake Mead includes the following assumptions:

- The 10th percentile data for the 80 percent ESP hydrology scenario provided by Reclamation show the ranges for elevations at Lake Powell and Lake Mead, including the 10 percent minimum, the 50 percent median, and the 90 percent maximum. It was assumed under the 10 percent minimum hydrology that the flows would be very low and steady year-round (approximately 7,000 cfs year-round steady). For a conservative assessment, the lowest extent of the 10th percentile for the 80 percent ESP hydrology scenario in the 4-year period was utilized.
- GIS acreage information was prepared utilizing the USGS's 2021 modified topobathymetric elevation data for Lake Powell, which is a topobathymetric digital elevation model comprised of four data sources published in 2021.
- The current Lake Powell reservoir level was retrieved from Reclamation for February 16, 2023, from the water operations: 40-day data sets (Reclamation 2023f).
- The current Lake Mead reservoir level was retrieved from Reclamation for February 2023 from the end-of-the-month elevations data sets (Reclamation 2023f).
- Lake Powell inundation (acres of water) are provided for the 10th percentile for the 80 percent ESP hydrology scenario, as well as the current level.
- Lake Mead inundation (acres of water) are calculated based on pre-inundation topographic maps for the 10th percentile for the 80 percent ESP hydrology scenario.
- All calculations were completed using the North American Datum 1983 (2011) Universal Transverse Mercator Zone 12N projected coordinate system.
- Exposed shoreline acres are two-dimensional estimates.

The method for assessing potential increased GHG emissions from decreased hydropower includes several assumptions made during the modeling process. The assumptions from the CRMMS of the Upper and Lower Basin are covered in **Section 3.3**, Methodology, with additional information in **Section 3.6**, Hydrologic Resources. Following the CRMMS of the Upper Basin, the GTMax modeling was only used for releases from Glen Canyon Dam. The modeling only analyzes penstock releases and does not analyze any potential releases from the river outlet works. Results from the GTMax modeling are only calculated for one week each month and then replicated for every week of the month. The CRMMS estimates monthly releases in the Upper and Lower Colorado Basin. The GTMax Model estimates hourly releases at Glen Canyon Dam. Megawatt hours derived from CRMSS/GTMax modeling were utilized and using the EIA energy conversion calculators, the amount of coal and natural gas necessary to produce the same amount of power was determined. Then, the EPA emission factors for GHG inventories were utilized to determine the metric tons per year (MT/year) of CO_2e for both natural gas and coal for each alternative (EPA 2022).

Impact Indicators

Impact indicators for air quality would remain the same as previously considered for the 2007 FEIS, including fugitive dust from shoreline exposure. In addition, impact indicators for air quality would include GHG emissions from alternative power sources (coal and natural gas) due to reduced hydropower. Reservoir elevation changes determine the amount of head available, which controls both energy and capacity, and penstock water releases are what power the powerplant turbines and lead to power generation.

Issue 1: How would changing flow characteristics affect potential exposed shoreline and fugitive dust?

Summary

The projected exposed shoreline acreages under Action Alternative 1 and Action Alternative 2 are less than that projected under the No Action Alternative at Lake Powell. The projected exposed shoreline acreages under Action Alternative 1 and Action Alternative 2 are also less than that projected under the No Action Alternative at Lake Mead. Although Action Alternative 2 was not analyzed with exposed shoreline acreages, due to potential additional DROA releases, Action Alternative 2 would likely result in less exposed shoreline acreages than the No Action Alternative and Action Alternative 1.

As reservoir elevations decrease and more shoreline is exposed, the potential for increased fugitive dust emissions increases. However, an increase in fugitive emissions from increased exposed shoreline would potentially be limited at Lake Powell. This is because the increased exposure of acreage could be comprised largely of sandstone, which is not conducive to generating PM_{10} standard fugitive dust emissions. There is also a significant potential for local "dust devils" and/or regional haboobs (intense dust storms), exposure to toxins in dust, and human health effects. With decreasing water levels, additional dust would affect local air quality and public health.

Without years of baseline monitoring for PM within the impact reach, changes in fugitive dust emissions would be difficult to determine. However, documentation of dust emissions has been studied at other western United States state and national parks in hopes of developing wind erosion vulnerability maps at local to regional scales. This documentation has characterized the physical and chemical properties of dust to better understand how dust influences atmospheric properties, ecosystem functions, and human health.

Although not included in this assessment, the application of mitigation strategies may also be needed due to local and regional dust impacts, including, but not limited to, mapping riparian areas for the highest potential restoration opportunities, implementing managed vegetation, allowing for shallow flooding that also affects river dynamics and HFEs, and conducting annual tillage methods and graveling. The National Resources Conservation Service is currently surveying soil content for other drying lakeshores, such as the Salton Sea in California, to formulate a dust risk index and to provide insight into potential airborne toxins and effects on human health.

No Action Alternative

Under the No Action Alternative, the 2007 Interim Guidelines and subsequent agreements would continue to guide operations in the Glen Canyon Dam to the Lake Mead reach. Releases from Lake Powell under poor hydrologic conditions would deplete Lake Powell, exposing a large acreage of increased shoreline at Lake Powell. The stage of water in the river would likely decrease from the Glen Canyon Dam to Lake Mead, but it would have comparatively little impact on dust issues. As water elevations continue to decline in Lake Powell, less water would be available for releases below this reach; this could result in additional air quality impacts at Lake Mead.

Lake Powell and Glen Canyon Dam

Under the No Action Alternative, the 2007 Interim Guidelines and subsequent agreements would continue to guide operations in Lake Powell. The current Lake Powell elevation is 3,522 feet, which is 57,454 acres of Lake Powell surface. Snowpack and hydrology would change water levels and exposed shorelines dramatically over a broad range. In the case of the no action alternative 10th percentile for the 80 percent ESP hydrology scenario (2023–2026), increased dust would be noted with much larger shorelines at Lake Powell, with an estimated exposed additional 28,000 acres. In the 2007 FEIS, the low Lake Powell elevation at the 10th percentile was projected for the year 2025 with about 17,000 acres of exposed shoreline (Reclamation 2007, Figure 4.6-1 and Table 4.6-1).

Glen Canyon Dam to Lake Mead, Lake Mead and Hoover Dam

The current Lake Mead elevation is 1,047 feet, which is 10,636 acres of Lake Mead surface. Snowpack and hydrology will change water levels and exposed shorelines dramatically over a broad range. In the case of no action 10th percentile for the 80 percent ESP hydrology scenario (2023–2026), increased dust would be noted with much larger shorelines at Lake Mead, with an estimated exposed additional 94,350 acres. In the 2007 FEIS under the No Action Alternative, Lake Mead elevation would be drawn down to 1,003 feet for 2025, resulting in approximately 89,000 acres of exposed shoreline (Reclamation 2007, Figure 4.6-2 and Table 4.6-2).

Action Alternative 1

Lake Powell and Glen Canyon Dam

Under Action Alternative 1, shoreline exposures may still vary significantly. For the Action Alternative 1 10th percentile for the 80 percent ESP hydrology scenario (2023–2026), increased dust would remain an issue, with an estimated exposed additional 8,000 acres at Lake Powell. The Action Alternative 1 10th percentile low-end elevation is 3,500 feet, which is 49,388 acres of Lake Powell surface. For Action Alternative 1, this would result in a decrease of about 70 percent in exposed shoreline compared with the No Action Alternative. Action Alternative 1 would yield the higher potential to reduce dust emissions and less impacts on air quality. However, there would still be an increase in exposed shoreline, and this increase would potentially have a negative effect on air quality. As sediment comprises a small percentage of the shoreline, the increase in acreage susceptible to wind erosion would be reduced and would not exceed the PSD Class II threshold or the state or national AAQS.

Glen Canyon Dam to Lake Mead, Lake Mead, and Hoover Dam

Under Action Alternative 1, shoreline exposures may still vary significantly. For the Action Alternative 1 10th percentile for the 80 percent ESP hydrology scenario (2023–2026), increased dust would remain an issue, with an estimated exposed additional 74,350 acres at Lake Mead. The Action Alternative 1 10th percentile low-end elevation is 950 feet, which is 30,636 acres of Lake Mead surface. For Action Alternative 1, this would result in a decrease of about 20 percent in exposed shoreline compared with the No Action Alternative. Action Alternative 1 would yield the higher potential to reduce dust emissions and less impacts on air quality. However, there would still be an increase in exposed shoreline, and this increase would potentially have a negative effect on air quality. The increase in acreage susceptible to wind erosion could potentially contribute to an exceedance of the PSD Class II threshold or the state or national AAQS.

Action Alternative 2

Lake Powell and Glen Canyon Dam

Action Alternative 2 includes potential additional DROA releases; otherwise, it would be similar to the air quality effects of Action Alternative 1, which was analyzed in detail above. Under Action Alternative 2, shoreline exposures may still vary significantly. For Action Alternative 2, increased dust would remain an issue, although the 10th percentile for the 80 percent ESP hydrology scenario (2023–2026) was not calculated to determine an estimated exposed additional acreage at Lake Powell. However, there would still be a decrease in exposed shoreline compared with the No Action Alternative. As stated, with potential for additional DROA releases, Action Alternative 2 could even yield the higher potential to reduce dust emissions and less impacts on air quality, compared with the No Action Alternative and Action Alternative 1. However, Reclamation would still anticipate an increase in exposed shoreline, and this increase would potentially have a negative effect on air quality. As sediment comprises a small percentage of the shoreline, the increase in acreage susceptible to wind erosion would be reduced and would not exceed the PSD Class II threshold or the state or national AAQS.

Glen Canyon Dam to Lake Mead, Lake Mead and Hoover Dam

Action Alternative 2 includes potential additional DROA releases; otherwise, it would be similar to the air quality effects of Action Alternative 1, which was analyzed in detail above. Under Action Alternative 2, shoreline exposures may still vary significantly. For Action Alternative 2, increased dust would remain an issue, although the 10th percentile for the 80 percent ESP hydrology scenario (2023–2026) was not calculated to determine an estimated exposed additional acreage at Lake Mead. However, there would still be a decrease in exposed shoreline compared with the No Action Alternative. As stated, with potential for additional DROA releases, Action Alternative 2 could even yield the higher potential to reduce dust emissions and less impacts on air quality compared with the No Action Alternative and Action Alternative 1. However, Reclamation would still anticipate an increase in exposed shoreline, and this increase would potentially have a negative effect on air quality. The increase in acreage susceptible to wind erosion would be reduced and would not exceed the PSD Class II threshold or the state or national AAQS.

Cumulative Effects

The cumulative effects are the impacts of the proposed alternatives combined with other regional water supply or closely related projects in the region. If one of the Glen Canyon Dam/Smallmouth Bass flow options were implemented, water would be released through the river outlet works. This would have no cumulative effect on fugitive dust air quality emissions.

Issue 2: How would lake reservoir elevations and releases impact power generation and GHG emissions?

Summary

Action Alternatives 1 and 2 result in significantly more power generation at Glen Canyon Powerplant compared with the No Action Alternative under low hydrology scenarios. This is particularly true in 2025–2026 when lake elevations under the No Action Alternative could drop below minimum power pool. Annual releases at Lake Mead are higher under the No Action Alternative, leading to less power generation at Hoover Powerplant under Action Alternative 1 across most hydrologic scenarios. Action Alternative 2 shows greater generation compared with the No Action Alternative due to the potential additional DROA releases. The difference is more varied at higher hydrologic scenarios due to the possibility of the dams releasing under different operational tiers.

Because Action Alternatives 1 and 2 result in significantly more power generation at Glen Canyon Powerplant compared with the No Action Alternative under low hydrology scenarios, the difference between the power generated for the No Action Alternative and Action Alternative 2 are compared. This difference is 1,293,755 megawatt hour (MWh) and the GHG emissions under the No Action Alternative for both coal and natural gas were calculated and compared with both total 11-state GHG emissions at 1,226.3 million MT CO_2e in 2010 and total US GHG emissions at 6,810.3 million MT CO_2e in 2010 (Reclamation and NPS 2016) (**Table 3-27**). Increases in GHG emissions for the No Action Alternative compared with Action Alternative 2 would be small, at approximately 442,360.81 MT/year of CO_2e for coal and 255,216.75 MT/year of CO_2e for natural gas. However, the totality of climate change impacts is not attributable to any single action. Albeit a small contribution, this project-related emission, in combination with a variety of GHG emission sources around the world, could exacerbate climate-related impacts.

No Action Alternative

As discussed in **Section 3.12.2**, Hydropower, under the No Action Alternative, annual releases from Lake Powell and Lake Mead would continue in the lower elevation tier, as outlined in the 2007 Interim Guidelines. At these rates, the likelihood of water elevations dropping below the minimum power pool at Lake Powell and Lake Mead rises drastically, potentially changing the degree to which electricity demand is met within the region with either non-emissive hydropower, wind, or solar powerplants, or emission-producing powerplants, such as fossil fuel-fired powerplants that can directly affect air quality and related resources. These air quality changes can also affect GHGs that can influence climate change. **Section 3.12.2**, Hydropower, also includes tables showing the analyses for annual energy generation at the Glen Canyon, Hoover, Parker, and Davis Powerplants for the

2024–2026 year and the likelihood of lake elevations dropping below the minimum power pool at all major powerplants. The 10th percentile of the modeled annual generation values from these tables were selected. **Table 3-27**, below, presents the estimated increase of GHGs for the No Action Alternative.

Table 3-27
Reduction of Annual Energy Generation and Associated GHG Emissions

Measure	No Action Alternative 10th Percentile	Action Alternative 1 10th Percentile	Action Alternative 2 10th Percentile
2024 Total - Glen Canyon, Hoover, and Parker-Davis Generation MWh	4,549,905	4,865,379	4,892,220
2025 Total - Glen Canyon, Hoover, and Parker-Davis Generation MWh	3,507,459	4,555,799	4,615,470
2026 Total - Glen Canyon, Hoover, and Parker-Davis Generation MWh	2,268,589	4,622,749	4,711,292
Largest Difference in MWh from Action Alternative 2	2,442,703	N/A	N/A
Coal - Mixed (Electric Power Source) (MT/year CO2e)	835,209	N/A	N/A
% of 11-State GHG Emissions	0.07	N/A	N/A
% of US GHG Emissions	0.01	N/A	N/A
Natural Gas (MT/year CO2e)	481,868	N/A	N/A
% of 11-State GHG Emissions	0.04	N/A	N/A
% of US GHG Emissions	0.007	N/A	N/A

The calculated GHG emissions under the No Action Alternative can also be compared with both total 11-state GHG emissions at 1,226.3 million MT CO_2e in 2010 and total US GHG emissions at 6,810.3 million MT CO_2e in 2010 (Reclamation and NPS 2016) (**Table 3-27**). Under the No Action Alternative, the reduction of hydropower could result in GHG emissions of 835,209 MT/year (0.835 million MT/year) with coal as the replacement power source, or 481,868 MT/year (0.482 million MT/year) with natural gas as the replacement power source. Differences in GHG emissions from the No Action Alternative range from 0.07 percent (coal) to 0.04 percent (natural gas) relative to total 11-state GHG emissions, and from 0.01 percent (coal) to 0.007 percent (natural gas) relative to total US GHG emissions.

Action Alternative 1

Under Action Alternative 1, elevations at Lake Powell would be protected at 3,500 feet allowing hydroelectric generation to continue at Glen Canyon Power Plant. This would result in a considerably smaller chance of dropping below the minimum power pool. However, protecting elevations at Lake Powell could result in a decrease in elevation at Lake Mead. This would lead to significantly less generation at Hoover Power Plant. These results show continued power generation at Glen Canyon Power Plant with impacts on generation at Hoover Power Plant. Overall, power generation across these facilities is higher compared with the No Action Alternative. Therefore, there would be no increase in GHG emissions due to alternative power sources for Action Alternative 1 compared with the No Action Alternative.

Action Alternative 2

Under Action Alternative 2, different allocations would redirect water below Hoover Power Plant. This would have no impact on hydroelectric generation at Glen Canyon and Hoover Power Plants compared with Action Alternative 1. There would be slight changes in impacts on generation at Parker and Davis Power Plants compared with Action Alternative 1. The potential additional releases from the Upper Basin under DROA would result in higher lake elevations and releases at Lake Powell and Lake Mead. These conditions would lead to greater capacity and generation potential at Glen Canyon and Hoover Powerplants. The additional potential DROA releases would have slight impacts on Parker and Davis Powerplants. However, these slight impacts would not increase GHG emissions due to alternative power sources for Action Alternative 2. Therefore, there would be no increase in GHG emissions due to alternative power sources for Action Alternative 2 compared with the No Action Alternative; however, the No Action Alternative would require alternative power and would increase GHG emissions.

Cumulative Effects

GHG emissions are inherently cumulative impacts because climate change is a global problem and the emissions from any single project alone would be negligible. The cumulative impacts are the impacts of the proposed alternatives combined with other regional water supply or closely related projects in the region. If one of the Glen Canyon Dam/Smallmouth Bass flow options were implemented, water would be released through the river outlet works that do not include power generation, resulting in a decrease in power generation. The potential operational changes included in the Glen Canyon Dam would result in a decrease in power generation at the Glen Canyon Powerplant. This reduction would be offset by the purchase of replacement power. The impacts on hydropower would potentially increase GHG emissions due to more emissive alternative power sources such as coal and natural gas. However, when calculated, the potential GHG emissions from coal and natural gas alternatives are a very small percentage of the 11-state and US GHG emissions.

3.10 Visual Resources

3.10.1 Affected Environment

Visual resources are the physical features that make up the visible landscape, including land, water, vegetation, topography, and human-made features such as buildings, roads, utilities, and structures. They also include the response of viewers to those features. This SEIS builds on the 2007 FEIS (Reclamation 2007), which identified the following visual resource issues that may be affected by the No Action Alternative and action alternatives:

- Attraction features
- Extent (height) of visible calcium carbonate ring
- Exposure of sediment deltas at reservoir inflow areas

Additionally, under this SEIS, based on proposed changes to the flow rate of the Colorado River between Glen Canyon Dam and Lake Mead, as well as potential changes in water availability in the Lower Division States, the following visual resource issues may also be affected:

- Landscape character adjacent to the Colorado River between Glen Canyon Dam and Lake Mead, including through the Grand Canyon
- Broader landscape modifications from reduced water availability, including in irrigated, agricultural landscapes within the Lower Division States

Lake Powell and Glen Canyon Dam Reach

Attraction Features

The landscapes of the Lake Powell and Glen Canyon area are characterized by sweeping vistas of red rock towers, buttes, and mesas typical of the Colorado Plateau's physiographic province (Fenneman 1931). The presence of Navajo Sandstone and desert varnish dominates the existing landscape character with the introduction of water, associated with Lake Powell, framing these natural features. The 2007 FEIS identified three attraction features:

- **Rainbow Bridge**: Contained within Rainbow Bridge National Monument, established in 1910, it was originally only accessible via the rugged Wetherill Trail from Navajo Mountain. Today, no facilities support the visitation of Rainbow Bridge National Monument. All infrastructure (docks and restrooms) were relocated to the main channel in 2021, due to narrowing of the canyon and a delta that has formed at the back of the canyon. Some small, motorized vessels may be able to access the monument; however, they must beach their boat, and the walk may be through very soft sediment to reach the trail. Based on lower lake elevations, visitors do not see water under or near the Rainbow Bridge. Therefore, while Rainbow Bridge is an important visual resource, the potential impacts on access would be the primary effect on visitors, which are described in **Section 3.14**, Recreation.
- **Cathedral in the Desert**: This feature was inundated by the waters of Lake Powell as the reservoir filled. This feature is only exposed at lower Lake Powell elevations, and it is

completely visible and accessible when reservoir elevations are below 3,550 feet. However, may not be boatable at reservoir elevations below 3,525 feet.

- **Glen Canyon Dam**: The American Society of Civil Engineers considers it one of the finest examples of concrete thin arch dams in the United States.

Calcium Carbonate Rings

As described in the 2007 FEIS, Lake Powell has deposits of calcium carbonate, which become visible as reservoir levels decrease. At lower lake elevations, the colorful sandstone canyon walls show a white band of calcium carbonate deposit between the full reservoir elevation and the lower reservoir elevation, which contrast with the natural, red-colored sandstone. Motorists would view the calcium carbonate ring on Utah State Route 95 (near Hite, Utah), boaters would view it on Lake Powell, recreationists would see it at developed and undeveloped recreation areas (for example, Hite, Bullfrog, Halls Crossing, Antelope Point, and Wahweap), and hikers would see it on trails adjacent to Lake Powell.

Sediment Deltas

As described in the 2007 FEIS, sediment deltas appear as expansive, deep, and eroding mud flats, cut by river channels. Sediment exposed for more than a few months is soon colonized by tamarisk, an invasive shrub. Sediments carried by the Colorado River and the San Juan, Dirty Devil, and Escalante Rivers are deposited near the inflow areas of Lake Powell, forming downstream-progressing deltas. These sediment deltas are considered a visual distraction, particularly as the reservoir elevation decreases and the deltas become more visible. The sediment deltas can be seen from viewing areas, including Utah State Route 95 (Utah Bicentennial Scenic Byway), scenic overlooks adjacent to these inflow areas, and water-based recreationists on Lake Powell.

Glen Canyon to Lake Mead

Attraction Features

This portion of the river, including GCNP, are heavily visited. It includes world-renowned whitewater rafting and other recreation opportunities along the Colorado River (see **Section 3.14**, Recreation, for more information).

Calcium Carbonate Rings

This portion of the Colorado River does not include visible calcium carbonate rings, as it is not contained within an area of fluctuating reservoir levels (e.g., Lake Powell or Lake Mead).

Sediment Deltas

This portion of the Colorado River does not include sediment deltas, as described for Lake Powell and Lake Mead.

Colorado River Landscape Character

The existing landscape character along the Colorado River is defined by towering cliff faces with banded rock strata containing a variety of colors, including reds, oranges, grays, browns, and white. Vegetation along the river is mostly comprised of riparian species such as native willows, nonnative and invasive tamarisk (salt cedar), and isolated areas of cottonwoods as well as cattails, bulrushes, and reeds in return-current channels (backwaters), channel margins, and mouths of tributary streams from Glen Canyon Dam downstream to Lake Mead. These tributary streams form numerous side canyons leading away from the Colorado River, with many of these side canyons only accessible from the river. Vegetation farther upslope along rock terraces includes saltbush, arrowweed, rabbitbrush, and other arid-adapted plant species. Previously planned HFEs from Glen Canyon Dam, to recreate natural floods common before the construction of the Glen Canyon Dam, have allowed for the transportation and deposition of sand, resulting in the formation of natural sandbars along the river. In some areas, these HFEs can strip vegetation along the existing sandbars, including tamarisk (salt cedar), allowing the landscape to appear more similar to its natural character.

Lake Mead to Hoover Dam

Attraction Features

The Lake Mead and Hoover Dam area landscapes are similar to those described for the Lake Powell area, except the adjacent landscapes are more typical of the Basin and Range physiographic province, characterized by parallel, north/south-oriented mountain ranges surrounded by nearly level, typically undrained basins (Fenneman 1931). As described in the 2007 FEIS, one attraction feature was identified:

- **Hoover Dam**: A major destination and national landmark with high levels of visitation, in 1955, it was selected as one of the seven engineering wonders in the United States by the American Society of Civil Engineers. Since the Hoover Dam is located in the narrow, steep-walled Black Canyon, only a small portion of Lake Mead is visible from Hoover Dam and adjacent visitor facilities.

Calcium Carbonate Rings

Similar to Lake Powell and as described in the 2007 FEIS, Lake Mead also has deposits of calcium carbonate, which become visible as reservoir levels decrease. At lower lake elevations, the steep rock slopes, canyon walls, and islands show a white band of calcium carbonate deposit between the full reservoir elevation and the lower reservoir elevation, which contrasts with the natural rock colors. Motorists would view the calcium carbonate ring on US Highway 93 (between Boulder City, Nevada, and Hoover Dam), boaters would view it on Lake Mead, and hikers would see it on trails adjacent to Lake Mead.

Sediment Deltas

As described in the 2007 FEIS, sediment deltas have built up at the confluence of the Virgin River and Muddy River at the upper Overton Arm and at upper Lake Mead (Iceberg Canyon, Pearce Basin, and lower Granite Gorge). Sediment deltas are visible primarily to water-based recreationists, and visitors to LMNRA at Overton Beach and Pearce Ferry can also view them.

Broader Landscape Character

Availability of water from the Colorado River has resulted in large areas of irrigated landscapes, including agricultural lands in Nevada, Arizona, and California (Lower Division States), which have altered the existing, natural landscapes. This increased water availability has introduced vivid greens into these landscapes, associated with crops and ornamental plantings, which expand the influence of the Colorado River into adjacent arid lands beyond the narrow, natural riparian corridor.

3.10.2 Environmental Consequences

Methodology

Similar methods were used for the analysis of potential impacts on visual resources as in the 2007 FEIS for the assessment of effects on attraction features, extent of visible calcium carbonate ring, and exposure of sediment deltas at reservoir inflow areas. Based on lowering lake levels associated with Lake Powell, at and below 3,550 feet, the analysis of effects on attraction features assumes the Cathedral in the Desert would be visible (and accessible) if these supplemental interim guidelines needed to be implemented. The assessment of effects on landscape character adjacent to Lake Powell and Lake Mead used the same methods identified in the 2007 FEIS. This includes using the latest 80 percent ESP analysis's 10th percentile reservoir elevations, developed by Reclamation using the CRMMS, with March 2025 selected for Lake Powell and September 2025 selected for Lake Mead. The height of the calcium carbonate ring was calculated as the distance in feet from full pool elevations of Lake Powell (3,700 feet) and Lake Mead (1,221 feet) to the applicable 10th percentile reservoir elevation. The assessment of effects from sediment deltas considers these 10th percentile reservoir elevation and tiers to the analysis conducted in the 2007 FEIS.

Two new analysis items, Colorado River Landscape Character and Broader Landscape Character, were added based on changes in hydrological conditions associated with the No Action Alternative as well as management direction associated with the action alternatives. To assess potential changes to landscape character along the Colorado River (between Glen Canyon Dam and Lake Mead), this analysis focuses on a qualitative assessment of effects associated with lower flow rates as well as the potential inability to conduct HFE from Glen Canyon Dam. This analysis considers and references analyses contained in **Section 3.13** (Riparian Vegetation portion of Biological Resources) and **Section 3.14**, Recreation, which assess the effects of the different flow rates resulting from the different alternatives on the prevalence of riparian vegetation and the visibility of river features including Separation and Pearce Ferry rapids, respectfully. The assessment of potential impacts on the broader landscape character in the Lower Division States considered changes in annual Colorado River water supplies available to these states to identify the extent of large-scale changes to visual character in irrigated landscapes including those associated with agricultural production. This analysis considers and references assessment items contained in **Section 3.16**, Socioeconomics including the effect of each alternative's proposed distribution of water on agricultural operations in these areas.

Impact Analysis Area

The visual resource impact analysis area was defined as the area within 5 miles of the Colorado River and full pool elevations of Lake Powell and Lake Mead. The 2007 FEIS did not specifically identify an analysis area for visual resources, but based on the typical threshold between the foreground-middleground visual distance zone and background visual distance zone where views of the change in management could attract attention in the landscape, this analysis area was selected to facilitate the assessment of the most intense potential impacts. Visual effects beyond this geographic scope area were considered, where appropriate, including the effects on the broader landscape character associated with potential decreased water availability for the Lower Division States.

Assumptions

- The analysis methods are consistent with the 2007 FEIS. Based on lowering water levels associated with Lake Powell, the assessment of visibility (and access) to Cathedral in the Desert assumed this would occur for all alternatives if these supplemental interim guidelines would need to be implemented.
- Deceasing flow rates along the Colorado River, and the inability to conduct HFE from Glen Canyon Dam, would modify the river corridor's natural, visual character though limiting natural flooding processes including through the Grand Canyon.
- Decreasing water availability for the Lower Division States would result in large-scale changes to visual character in irrigated landscapes including those associated with agricultural production.

Impact Indicators

- **Attraction Features:** Qualitative assessment describing the effects from continued visibility and access to Cathedral in the Desert as well as more of Glen Canyon Dam and Hoover Dam becoming visible on their upstream side, tiering to the results from the 2007 FEIS considering current reservoir elevations and the latest 80 percent ESP analysis's 10th percentile reservoir elevations.
- **Calcium Carbonate Rings:** Potential height (in feet) of the calcium carbonate ring at Lake Powell and Lake Mead for each alternative considering the latest 80 percent ESP analysis's 10th percentile reservoir elevations.
- **Sediment Deltas:** Qualitative assessment tiering to the analysis from the 2007 FEIS considering the latest 80 percent ESP analysis's 10th percentile reservoir elevations.
- **Colorado River Landscape Character:** Qualitatively describe the effect associated with proposed flow rates and the potential to conduct HFE from Glen Canyon Dam under each alternative considering modeling associated with **Section 3.13** (Riparian Vegetation portion of Biological Resources) and **Section 3.14**, Recreation.
- **Broader Landscape Character:** Qualitatively describe the effects associated with potential decreases in water availability for the Lower Division States on the broader landscape character. This includes considering modeling associated with potential changes to crop production as a result of proposed distribution of water as described in **Section 3.16**, Socioeconomics.

Issue 1: How would management of reservoir elevations affect visibility of attraction features?

Summary

Visibility and access to Cathedral in the Desert would be similar among all alternatives. Due to lower projected elevations for Lake Powell and Lake Mead associated with the No Action Alternative, more of the upstream side of Glen Canyon and Hoover Dams would be visible compared with both action alternatives.

No Action Alternative

Under the No Action Alternative, Lake Powell would likely remain below 3,550 feet through the end of 2026. Based on this elevation, Cathedral in the Desert would be visible and accessible under the No Action Alternative through the planning period. This same modeling projects pool elevations for Lake Powell could drop below 3,450 feet in 2024, 2025, and 2026, which would expose more of the upstream side of Glen Canyon Dam. The impacts associated with more of Glen Canyon Dam becoming visible would be similar to the effects described in the 2007 FEIS. Similarly, more of the upstream side of Hoover Dam would become visible due to lowering lake elevations in Lake Mead, which based on modeling, would approach and may drop below 900 feet in 2026.

Action Alternative 1

Similar to the No Action Alternative, Cathedral in the Desert would be visible and accessible under this alternative. Based on proposed management to maintain Lake Powell at 3,500 feet or above, less of the upstream side of Glen Canyon Dam would be exposed under this alternative. In a similar manner, the management of water levels within Lake Mead would remain above 925 feet through 2026 resulting in less of the upstream side of Hoover Dam becoming visible under this alternative compared with the No Action Alternative.

Action Alternative 2

Similar to the No Action Alternative and Action Alternative 1, Cathedral in the Desert would be visible and accessible under this alternative. Similar to Action Alternative 1, less of the upstream side of Glen Canyon Dam and Hoover Dam would be exposed as compared with the No Action Alternative.

Cumulative Effects

If one of the Glen Canyon Dam/Smallmouth Bass flow options were implemented, there would be no changes to lake levels in Lake Powell or Lake Mead. Therefore, no additive cumulative effects would occur on attraction features and effects would be the same as described above for each alternative. Future increases in consumptive use of Colorado River water in the upper division, intrastate water transfers in the Lower Division States (e.g., Quantification Settlement Agreement water transfers), implementation of the Lower Colorado River Multi-Species Conservation Plan (LCR MSCP), and various requirements and constraints applied to the operation of the Colorado River system were included in modeling of future system conditions.

Issue 2: How would management of reservoir elevations affect landscape character including visibility of calcium carbonate rings and sediment deltas?

Summary

The effects on landscape character associated with visibility of calcium carbonate rings and sediment deltas would be most prominent associated with the No Action Alternative based on taller calcium carbonate rings and more extensive sediment deltas, which would become populated by vegetation including tamarisk, introducing bright greens into the landscape contrasting with the arid landscape's natural character. These changes in landscape character would be visible to boaters on Lake Powell and Lake Mead, motorists on adjacent highways, and recreationists at developed and undeveloped recreation areas. Due to the addition of potential DROA releases each year (up to 500,000 af to help protect Lake Powell elevation of 3,500 feet) under Action Alternative 2, water levels in Lake Powell and Lake Mead would be higher resulting in shorter calcium carbonate rings and less expansive sediment deltas than the No Action Alternative and Action Alternative 1.

No Action Alternative

Modeled reservoir elevations for March 2025 indicate a low Lake Powell reservoir elevation of 3,496 feet under the No Action Alternative, which would create a potential calcium carbonate ring of 204 feet in height. Modeled reservoir elevations for September 2025 indicate a low Lake Mead reservoir elevation of 988 feet under the No Action Alternative, which would create a potential calcium carbonate ring of 233 feet in height. As described in the 2007 FEIS, sediment deltas would continue to build up over time and would be visible as reservoir elevations drop, including under the current No Action Alternative. The expanding sediment deltas would become populated by vegetation, including tamarisk, which would introduce bright greens into the landscape, contrasting with the arid landscapes adjacent to Lake Powell and Lake Mead.

Both the calcium carbonate ring and sediment deltas would modify the landscape character along the edge of Lake Powell with these modifications visible for motorists on Utah State Route 95, boaters on the Lake Powell, recreationists at developed and undeveloped recreation areas, and hikers on trails adjacent to Lake Powell. Similarly, the calcium carbonate ring and sediment deltas would modify the landscape character along the edge of Lake Mead with these modifications being visible for motorists on US Highway 93 (between Boulder City, Nevada, and the Hoover Dam), boaters on Lake Mead (including visitors to Overton Beach and Pearce Ferry), and hikers on trails adjacent to Lake Mead.

Action Alternative 1

Modeled reservoir elevations for March 2025 indicate a low Lake Powell reservoir elevation of 3,500 feet under Action Alternative 1, which would create a potential calcium carbonate ring 200 feet in height. Modeled reservoir elevations for September 2025 indicate a low Lake Mead reservoir elevation of 997 feet under Action Alternative 1, which would create a potential calcium carbonate ring of 224 feet in height. Based on potential higher lake elevations associated with this alternative, the sediment deltas would be less extensive than under the No Action Alternative. Due to the shorter calcium carbonate ring and less extensive sediment deltas, Action Alternative 1 would result in less modification to the landscape character along the edge of Lake Powell and Lake Mead, including impacts on viewers, than the No Action Alternative.

Action Alternative 2

Modeled reservoir elevations for March 2025 indicate a low Lake Powell reservoir elevation of 3,542 feet under Action Alternative 2, which would create a potential calcium carbonate ring of 158 feet in height. Modeled reservoir elevations for September 2025 indicate a low Lake Mead reservoir elevation of 1,001 feet under Action Alternative 2, which would create a potential calcium carbonate ring of 220 feet in height. Based on potential higher lake elevations associated with this alternative, the sediment deltas would be less extensive than under the No Action Alternative and Action Alternative 1. Due to the shorter calcium carbonate ring and less extensive sediment deltas, Action Alternative 2 would result in less modification to the landscape character along the edge of Lake Powell and Lake Mead, including impacts on viewers, than the No Action Alternative or Action Alternative 1.

Cumulative Effects

If one of the Glen Canyon Dam/Smallmouth Bass flow options were implemented, there would be no changes to lake levels in Lake Powell or Lake Mead. Therefore, no additive cumulative effects would occur on landscape character near Lake Powell and Lake Mead with the same effects described above occurring for each alternative. Future increases in consumptive use of Colorado River water in the Upper Division States, intrastate water transfers in the Lower Division States (e.g., Quantification Settlement Agreement water transfers), implementation of the LCR MSCP, and various requirements and constraints applied to the operation of the Colorado River system were included in modeling of future system conditions.

Issue 3: How would management of releases from Glen Canyon Dam affect landscape character along the Colorado River?

Summary

The No Action Alternative would initially have less impacts on the landscape character than the action alternatives, as the No Action Alternative does not include reducing flows below 7.0 maf; however, if Lake Powell were to drop to dead pool, these impacts would be more extensive and immediate compared with Action Alternatives 1 and 2. Under Action Alternative 1, the different release tiers would temper these impacts with the goal of maintaining consistent flows along the Colorado River (including through the Grand Canyon) while keeping Lake Powell above 3,500 feet. Action Alternative 2 would result in similar impacts as Action Alternative 1, except due to potential releases from Upper Basin reservoirs, would likely result in higher levels in Lake Powell and higher flows from Glen Canyon Dam. This would result in lower impacts on the landscape character associated with Action Alternative 2 along the Colorado River compared with Action Alternative 1.

No Action Alternative

The No Action Alternative includes lowering releases from Glen Canyon Dam, as Lake Powell elevations drop, resulting in releases as low as 7.0 maf when elevations drop below 3,525 feet. Since the No Action Alternative does not include reducing releases from Glen Canyon Dam under 7.0 maf, including if Lake Powell drops below power pool but remains above dead pool, there would be minor incremental impacts on the landscape character along the Colorado River (including through the Grand Canyon). Current trends of increasing bank armoring, associated with expanding riparian vegetation areas (including tamarisk), would continue under the No Action Alternative.

Based on the current 80 percent ESP modeling, it is not anticipated that Lake Powell would reach dead pool elevation during the planning period. If the elevation of Lake Powell were to drop below dead pool, flows from Glen Canyon Dam could dramatically decrease, resulting in more extensive impacts on the landscape character, including the appearance of river features previously not visible under current conditions. Additionally, the positive influence of the moving, turbulent Colorado River adds to the existing landscape character that would be degraded if releases from Glen Canyon Dam would be dramatically reduced. (For more information on the impacts on riparian vegetation under the No Action Alternative, refer to **Section 3.13**; for impacts on recreation, including visibility of river features, refer to **Section 3.14**.)

Action Alternative 1

Action Alternative 1, as part of the Lower Elevation Release Tier (below 3,575 feet), includes a series of thresholds to reduce releases from Glen Canyon Dam. These thresholds are tied to lower Lake Powell elevations with an initial release set at 6.0 maf with increases based on the April elevation projection. Lower releases from Glen Canyon Dam would result in less water flowing along the Colorado River (and through the Grand Canyon), which could increase existing trends of bank armoring associated with more extensive riparian vegetation (including tamarisk). Lower releases also could potentially limit the number of times a HFE could be triggered from Glen Canyon Dam, which would only occur when the HFE furthers maintenance of target reservoir elevations. These lower flows may also result in the appearance of river features previously not visible under current conditions and less movement of the river's natural sandbars.

If the yearly April elevation projection identifies that Lake Powell would be above 3,525 feet, resulting in releases of 7.0 maf or more, the impacts associated with this alternative would be similar to those described under the No Action Alternative. It would also avoid the increased impacts associated with the lower 6.0 maf releases from Glen Canyon Dam. Through management to maintain Lake Powell elevations above dead pool (3,370 feet), by reducing releases to balance gains and losses starting below 3,500 feet (potentially resulting in releases of less than 6.0 maf), impacts on the landscape character associated with the flowing, turbulent Colorado River and its effect on bank armoring and visibility of river features would increase and may include the inability to conduct HFEs from Glen Canyon Dam. (For more information on the impacts on riparian vegetation under Action Alternative 1, refer to **Section 3.13**; for impacts on recreation, including visibility of river features, refer to **Section 3.14**.)

Action Alternative 2

Impacts would be similar to those described for Action Alternative 1, but with the addition of potential water releases each year from Upper Basin reservoirs to help protect Lake Powell elevation 3,500 feet, up to 500,000 af, water levels in Lake Powell would likely remain higher under this alternative. Based on higher water levels in Lake Powell, the decreased releases from Glen Canyon Dam and its effects on landscape character associated with Action Alternative 1 would be tempered by this additional inflow of water into Lake Powell under this alternative. (For more information on the impacts on riparian vegetation under Action Alternative 2, refer to **Section 3.13**; for impacts on recreation, including visibility of river features, refer to **Section 3.14**.)

Cumulative Effects

If one of the Glen Canyon Dam/Smallmouth Bass flow options were implemented, there would be no changes to release amounts from Glen Canyon Dam. Therefore, no additive cumulative effects would occur on landscape character along the Colorado River downstream of Glen Canyon Dam, with the same effects described above occurring for each alternative. Future increases in consumptive use of Colorado River water in the Upper Division States, intrastate water transfers in the Lower Division States (e.g., Quantification Settlement Agreement water transfers), implementation of the LCR MSCP, and various requirements and constraints applied to the operation of the Colorado River system were included in modeling of future system conditions.

Issue 4: How would management of water availability for the Lower Division States affect landscape character?

Summary

The No Action Alternative would initially have lower impacts on the character of irrigated and agricultural landscapes within the Lower Division States compared with both action alternatives. As the elevation of Lake Mead continues to drop toward dead pool, under the No Action Alternative dramatic decreases in water availability could occur and it would affect all three Lower Division States. Both action alternatives establish a series of water supply adjustments based on lower elevations of Lake Mead to temper these impacts with Action Alternative 1 initially focusing shortages in Arizona and Nevada with potential further decreases for California if Lake Powell drops below 1,040 feet. Action Alternative 2 would have similar impacts; however, it would distribute water shortages across all three Lower Division States, resulting in more widely distributed, but less intense, effects on the character of irrigated and agricultural landscapes in the Lower Division States.

No Action Alternative

Since the No Action Alternative includes minor adjustments to the distribution of water for Arizona and Nevada (no adjustments for California), based on lowering Lake Mead elevations, there would initially be a limited incremental effect on irrigated landscapes, including those in agricultural use. As elevations in Lake Mead continue to drop toward dead pool (895 feet), the 80 percent ESP analysis identifies that lake levels could approach this threshold in 2026, and flows from Lake Mead could dramatically decrease. This would result in lower water deliveries than currently allocated affecting all three Lower Division States. Depending on the duration of these decreased water deliveries, the character of irrigated and agricultural landscapes within the Lower Division States would be modified through aridification of these areas, diminishing the vivid greens associated with crops and ornamental plantings. The influence of the Colorado River into adjacent lands would narrow as these areas would transition to their natural, arid condition, resulting in large-scale changes to the landscape character compared with the existing condition. (For more information on the impacts on agricultural operations under the No Action Alternative, refer to **Section 3.16**, Socioeconomics).

Action Alternative 1

Action Alternative 1 includes a series of water supply adjustments for the Lower Division States based on lower elevations of Lake Mead. If water levels in Lake Mead drop below 1,090 feet, similar effects as described under the No Action Alternative are anticipated. In 2024, if water levels drop below 1,040 feet, all three states would receive less water from the Colorado River under this alternative, with Arizona and Nevada experiencing the largest shortage. For 2025 and 2026, more reductions to water supplies could occur with all three states likely receiving lower deliveries associated with each lowering reservoir elevation tier.

As Lake Mead approaches dead pool, to avoid a dramatic decrease in water releases from Hoover Dam affecting all three Lower Division States, more reductions would occur. These include further reductions in water deliveries based on extraordinary circumstances, as described in Section 7(D) of the 2007 Guidelines. These reductions, to avoid reaching dead pool, would temper the impacts on the character of irrigated and agricultural landscapes within the Lower Division States, as described under the No Action Alternative. Lower water releases would potentially lead to aridification of areas affected by water shortages, diminishing the vivid greens associated with crops and ornamental plantings, but they would occur more gradually. The influence of the Colorado River into adjacent lands would begin to narrow, especially in Arizona and Nevada where larger water shortages are anticipated, as these areas would transition to their natural, arid condition. This would result in large-scale changes to the landscape character compared with the existing condition. (For more information on the impacts on agricultural operations under Action Alternative 1, refer to **Section 3.16**, Socioeconomics).

Action Alternative 2

Similar to Action Alternative 1, the same series of proposed water supply adjustments for the Lower Division States, based on lower elevations of Lake Mead, would occur. Under Action Alternative 2, all three Lower Division States would receive less water with shortages distributed between all users in these areas. Impacts on landscape character would be similar to those described for Action Alternative 1 except these effects would be distributed across the Lower Division States reducing effects in Arizona and Nevada while increasing effects on irrigated and agricultural landscapes in California. (For more information on the impacts on agricultural operations under Action Alternative 2, refer to **Section 3.16**, Socioeconomics).

Cumulative Effects

If one of the Glen Canyon Dam/Smallmouth Bass flow options were implemented, there would be no changes to water deliveries in the Lower Division States. Therefore, no additive cumulative effects would occur on the landscape character in these areas, with the same effects described above occurring for each alternative. Future increases in consumptive use of Colorado River water in the Upper Division States, intrastate water transfers in the Lower Division States (e.g., Quantification Settlement Agreement water transfers), implementation of the LCR MSCP, and various requirements and constraints applied to the operation of the Colorado River system were included in modeling of future system conditions.

3.11 Cultural Resources

3.11.1 Affected Environment

For the cultural resources affected environment, the data and discussion are summarized from Section 3.9, Cultural Resources, of the 2007 FEIS. New information was included when appropriate.

As defined in the 2007 FEIS, cultural resources "include historic and prehistoric buildings, structures, sites, and objects, including Indian sacred sites and traditional cultural properties." Historic properties are a subset of cultural resources (Reclamation 2007) that have special protections under the National Historic Preservation Act of 1966 as amended (NHPA). Per the implementing regulations of the NHPA, historic properties are districts, sites, buildings, structures, or objects that are listed on or eligible for listing on the National Register of Historic Places (NRHP) and includes properties of traditional religious and cultural importance to an Indian Tribe or Native Hawaiian organization that meet the NRHP criteria (36 CFR 800.16(l)(1)).

The NPS manages GCNP, LMNRA, and GCNRA (which includes Lake Powell) for recreation and resource protection. Reclamation manages water operations. The cultural resources in the portion of GCNRA below the Glen Canyon Dam and the cultural resources in the Grand Canyon are protected under the GCPA. The GCNP is also a designated United Nations Educational, Scientific, and Cultural Organization World Heritage Area.

Both agencies have NHPA agreements for the management of historic properties under their care. For example, Lake Mead's General Management Plan Amendment/Low-Water Plan/EA of December 2018 anticipates NPS actions as the land manager and the need for resource protection at lake elevations above 950 feet: "Archeological and historic resources in the park have been adversely impacted from past development, vandalism, illegal activities, and natural processes. Lowering lake levels would continue to expose formerly submerged resources, which could result in adverse impacts from visitor use or vandalism. The NPS would continue to undertake measures to minimize or mitigate potential impacts through monitoring, educating the public, and restricting use in sensitive areas." (DOI 2018) The LTEMP for the operations of the Glen Canyon Dam includes a Reclamation programmatic agreement (PA) to mitigate adverse effects on historic properties caused by dam operations.

Study Area and Area of Potential Effects

The 2007 Interim Guidelines were developed due to water shortages, "particularly under drought and low reservoir conditions" (Reclamation 2007). They identified the area of potential effects (APE) defined by Reclamation as the reaches of the Colorado River from Lake Powell to Imperial Dam. In the reach from Davis Dam to Imperial Dam, the APE consists of the Colorado River channel from bank to bank and the backwaters, lakes, and marshes connected to the river. This APE was used for the current NEPA analysis area and will be used in this document.

Identification Efforts

For the 2007 FEIS, Reclamation compiled all available previous research on cultural resources from the NPS and available literature. These data are summarized below. Additional, and more recent, data were provided by the NPS (NPS 2023k). Because the majority of the resources of concern were submerged during the creation of the lakes, no new data on archaeological sites are needed for this analysis. Cultural resources found in the deepwater zone of reservoirs are the least vulnerable to effects from wave action and other disturbances. Those in the operational zones are vulnerable, and those above the pool elevation are at risk for damage and disturbance by visitation (Reclamation 2007). A recent study by the NPS at the GCNRA of sites at Lake Powell confirmed this conclusion (Burns et al. 2022).

Section 106 of the National Historic Preservation Act and Tribal Consultation

Per Section 106 of the NHPA and its implementing regulations (36 CFR 800), Reclamation will consult with the Arizona, Nevada, Utah, and California State Historic Preservation Offices (SHPOs), Tribal Historic Preservation Officers (THPOs), affected Tribes without THPOs, and consulting parties regarding the effects of the undertaking on historic properties and the resolution of adverse effects not covered under existing agreement documents. Adverse effects on historic properties not covered by existing agreement documents will be resolved by the appropriate land managing agency in consultation with the SHPOs, THPOs, Tribes, and consulting parties per 36

CFR 800.6. A description of the Section 106 consultation to date, including a list of affected Tribes, can be found in **Chapter 4**, Consultation and Coordination.

Lake Powell and Glen Canyon Dam

Of the 518 historic properties recorded around Lake Powell during the Glen Canyon Project from 1956 and 1963 (prior to the inundation of Lake Powell), 447 sites were not subjected to excavation or testing (Reclamation 2007). In addition, resources of Tribal concern have been documented in the Lake Powell and Glen Canyon Dam area.

Glen Canyon Dam to Lake Mead

This reach extends from the GCNRA into the GCNP, the Navajo Indian Reservation, and the Hualapai Indian Reservation.

A survey of this reach in the 1990s identified 336 sites that may be affected by the operations of the dam; 313 were determined eligible, 14 ineligible, and 9 as unevaluated for listing on the NRHP. Within Glen Canyon, 53 archaeological sites have been identified within the GCNRA and the Navajo Nation along this reach; none of these 53 sites have had formal determinations of eligibility completed, and all are currently treated as eligible sites (NPS 2023j).

As discussed in LTEMP Section 3.8, research has shown that sediment within the active river channel and/or deposited by HFEs can be transported by the wind to terraces and source bordering aeolian deposits that contain historic properties (East et al. 2016). That wind-deposited sediment can help stabilize and preserve the archaeological properties in place (East et al. 2016). If used correctly, HFEs could benefit sediment deposition to keep archaeological resources that would otherwise be exposed through erosion. Current dam operations and the absence of HFEs have the potential to impact in situ preservation.

Lake Mead to Hoover Dam

Nearly 1,500 prehistoric and historic-aged resources have been documented in this reach; three of these (Hoover Dam, Lost City/Pueblo Grande de Nevada, and B-29 Heavy Bomber) are listed on the NRHP (Reclamation 2007). Hoover Dam is also a National Historic Landmark. Due to the advanced age of the reservoir, no comprehensive cultural surveys were conducted prior to inundation. Early surveys and site documentation focused on large, salient resources. Many documented sites have not yet been evaluated for inclusion in the NRHP. When water in Lake Mead rose in elevation from 1,083 feet to 1,102 feet in 1937, many of these resources were submerged.

Fluctuations in the water level from 1,083 to 1,226 feet have resulted in the repeated exposure of resources and wave action in that zone, which has adversely affected the resources' integrity (Reclamation 2007). However, submerged resources are likely to still maintain integrity for listing on the NRHP. Over 100 resources have been recorded in the Lake Mead operational zone (1,083–1,226 feet); some resources have been damaged or destroyed, while others retain a moderate to high level of integrity (NPS 2023k). Over 50 resources are below 1,083 feet and may retain integrity (NPS 2023k). Sonar scans indicated that thick sediments may be protecting some resources (Reclamation 2007).

Lake Mohave and Davis Dam

Previous surveys identified 89 sites within or adjacent to Lake Mohave and Davis Dam (Reclamation 2007). Resources between 628 and 647 feet have been subjected to wave action and likely have lost integrity; sites below 628 feet may still retain integrity. An NRHP-listed traditional cultural place (TCP) important to several Tribes is found within this reach.

Davis Dam to Parker Dam

This portion of the system is split into the river reach from Davis Dam to Upper Lake Havasu and the reach of Lake Havasu and Parker Dam.

Davis Dam to Upper Lake Havasu

Prehistoric and historic resources have been documented within this reach; however, many of them have been significantly impacted by development, flood events, and alterations to the reach during the 1950s (Reclamation 2007).

Lake Havasu and Parker Dam

Eight historic-age cultural resources have been documented beneath Lake Havasu, and 20 prehistoric sites have been documented at the edge of the lake or on islands or peninsulas in the lake (Reclamation 2007). Several historic-period Chemehuevi Indian villages are known to have been located along the river in the Chemehuevi Valley. Resources within the lake's current or historic operational zone (ranging from 450.5 to 445.8 feet) will have been affected by the rising and falling water levels. Resources that have remained submerged are likely to have been protected (Reclamation 2007).

Parker Dam to Imperial Dam

Limited inventories have been conducted in this reach. Only three individual resources have been recorded within the analysis area/APE; these are Parker Dam, Imperial Dam, and the Old Parker Road alignment. One historic district, the Parker Dam Historic District, extends into the analysis area/APE (Reclamation 2007). However, more cultural resources are likely present in this reach.

Imperial Dam to SIB

Very little data are available for the Imperial Dam to SIB reach. Two resources within the reach are listed on the NRHP: the Ocean-to-Ocean Bridge and the Yuma Crossing and Associated Sites NHL (Reclamation 2007). Because of the lack of inventories for this reach, currently unknown resources may be present.

Ethnographic Resources and Traditional Cultural Places

From time immemorial, the Colorado River and its canyons have been sacred places for Native communities. The Colorado River features prominently in the cosmology and culture of Indigenous peoples of the Southwest (Reclamation 2016). For the Tribes, the Colorado River and its canyons are living, sentient entities consisting of sacred spaces, the homes of their ancestors, the residence of the spirits of their dead, and the source of culturally important resources. Many Tribes see themselves as stewards of the Colorado River and its canyons, which are a vital part of the living world; caring for the river and the canyons is their responsibility.

The river and canyons are considered by many Indigenous groups to be a type of historic property known as a TCP. The Hualapai Tribe (Coulam 2011), the Hopi Tribe (Hopi CPO 2001), the Navajo Nation (Maldonado 2011), and the Pueblo of Zuni (Dongoske 2011) have all prepared NRHP nomination forms for the Colorado River and its canyons as a TCP.

3.11.2 Environmental Consequences

Methodology

In the 2007 FEIS, the 10th percentile as the "worst-case scenario" for Lake Powell was used for each alternative to assess the impacts of lake elevation on cultural resources. Based on this, the lowest Lake Powell water elevation accounted for was 3,496 feet. Anticipated lake elevations below 3,496 feet will be addressed in the current analysis. For Lake Mead, an elevation of 1,080 feet was used as the lowest elevation in the 2007 FEIS. In the current analysis, elevations below 1,080 feet will be assessed also using the 10th percentile as the worst-case scenario. For resources along the river, the 2007 FEIS state that "[P]rocesses that might result in a loss of integrity vary by reach and property type; consequently, methods of assessing effects differ by reach" (Reclamation 2007). However, the majority of impacts within the reaches were assessed by comparing anticipated flows between alternatives.

The USGS has conducted a study of the availability of windblown sediment by alternative in the reach between Glen Canyon Dam and Bright Angel Creek (Kasprak et al. 2023). Windblown (or aeolian) sediment can be important for the protection of archaeological sites from erosion. Dry sediment is transported by the wind from the riverbed to archaeological sites along the river where the sediment covers and protects the sites. The results of this study are discussed below.

Adverse effects on historic properties will be resolved by the appropriate land management agency based on existing mitigation documents and consultation under the NHPA Section 106 process (36 CFR 800).

Impacts Analysis Area

The impacts analysis area for cultural resources is consistent with that used by the 2007 FEIS. It consists of the reaches of the Colorado River from Lake Powell to Imperial Dam and in the reach from Davis Dam to Imperial Dam. The APE consists of the Colorado River channel from bank to bank and the backwaters, lakes, and marshes connected to the river.

Assumptions

The assumptions for the following analysis are:

- Archaeological site data, as discussed in the 2007 FEIS and without specific locations, were used.
- Impacts on cultural resources can be characterized based on projected lake elevations and river flows.

Impact Indicators

Impact indicators for this analysis are:

- Projected lake elevations that fall below levels previously analyzed by the 2007 FEIS that may expose historic properties to damage from wave action, wet/dry cycling, or increased visitation
- Projected changes in river flows that are not addressed within the LTEMP that may contribute to erosion and exposure of resources
- Availability of windblown sediments to protect archaeological sites
- Negative effects on TCPs that were not discussed in the 2007 FEIS or LTEMP FEIS
- Changes in access to sacred sites

Issue 1: How would changes in lake elevations from water releases from Lake Mead and from equalizing/balancing Lake Mead and Lake Powell affect previously submerged archaeological sites, as well as those at the lake margins?

Summary

All the alternatives would result in lake elevations that may further expose resources to damage from wave action, wet/dry cycling of fluctuating water levels, increased visitation, and unauthorized collection or vandalism. Both Action Alternative 1 and Action Alternative 2 would have fewer negative impacts on cultural resources at Lake Powell and Lake Mead than the No Action Alternative. Action Alternative 2 could have slightly fewer negative impacts on cultural resources than Action Alternative 1. Under the two action alternatives, lake levels would remain at least at or above the minimum power pool for Lake Powell and Lake Mead. This would protect those cultural resources below that level. Resources at the lake margins would still be vulnerable to wave action and wet/dry cycling, and resources above the lake elevation could be subjected to more visitation. Adverse effects on historic places would be resolved through land management agency using existing mitigation documents and the NHPA Section 106 process.

No Action Alternative

Under the No Action Alternative, Lake Powell's projected pool elevation for the 10th percentile through 2024 is 3,450 feet, which is below the minimum power pool. In 2025 through 2026, pool elevations for the 10th percentile are projected to dip below 3,450 feet and remain under the minimum power pool for the future. Newly exposed resources below 3,496 feet would likely be exposed for an extended period of time and may be prone to increased visitation; most of these resources are in canyons that are difficult to reach on foot but may be accessible via canyoneering. Negative impacts from wave action and wet/dry cycles may occur on newly exposed resources at lower elevations.

Lake Mead pool elevations are currently below 1,080 feet and, for the 10th percentile, are projected to dip under 1,000 feet by the end of 2024. Between 2025 and 2026, the 10th-percentile scenario is for the pool elevation at Lake Mead to dip below the power pool level of 950 feet by 2026, which would continue into the future. Known resources below 1,080 feet are primarily prehistoric sites recorded prior to the inundation of the lake; these would also be exposed for an extended period of time. These sites could be affected by wave action at the lake margins and wet/dry cycles, and they could see increased visitation from hikers.

Action Alternative 1

Under Action Alternative 1, Lake Powell's pool elevations at the 10th percentile could dip to the minimum power pool of 3,490 feet in 2024; however, the minimum power pool elevation of 3,490 feet would be protected except under extraordinary circumstances. Pool elevations are projected at the 10th percentile to be at or above 3,500 feet through 2025–2026 and beyond. Overall, pool elevations would be higher than they would be for the No Action Alternative, and they would remain above the minimum power pool. Therefore, impacts on cultural resources at Lake Powell for Action Alternative 1 are fewer than those for the No Action Alternative because fewer resources would be exposed for a shorter amount of time.

For Lake Mead, the pool elevations are projected at the 10th percentile to be as low as 960 feet in 2025 but around 975 feet in late 2025 and into 2026. The minimum power pool would be protected except under extraordinary circumstances. Because the power pool level of 950 feet would be maintained and fewer resources would be exposed, impacts on cultural resources under Action Alternative 1 would be less than those under the No Action Alternative.

Action Alternative 2

Impacts on cultural resources at Lake Powell and Lake Mead for Action Alternative 2 would be the same as those for Action Alternative 1. However, potential additional DROA contributions implemented to protect the 3,500-foot elevation of Lake Powell could lessen impacts on cultural resources at Lake Powell. If these releases moved Lake Powell to an elevation that allowed for higher releases—and resulting higher elevations at Lake Mead—impacts on cultural resources at Lake Mead could also be lessened.

Cumulative Effects

Reclamation has identified one reasonably foreseeable future project that may, in conjunction with the proposed near-term Colorado River operations, contribute to cumulative effects on cultural resources; this project is the Glen Canyon Dam/Smallmouth Bass flow options. Reclamation is proposing specific flow adjustments in water releases from the Glen Canyon Dam to control smallmouth bass establishment. All proposed flow options in the EA adhere to operational and regulatory constraints as outlined in the LTEMP FEIS. Reclamation is consulting with stakeholders regarding any potential adverse effects under Section 106 of the NHPA. If Reclamation determines there is an adverse effect on a historic property (which includes TCPs) or its contributing elements, those effects will be resolved under the LTEMP PA and the Nonnative Fish MOA, which is in development. If potential adverse effects can be mitigated, the project should not contribute to cumulative impacts in conjunction with the proposed near-term Colorado River operations.

Issue 2: How would changes in river flows from water releases from Lake Mead and from equalizing/balancing Lake Mead and Lake Powell affect archaeological sites along the river?

Summary

Both Action Alternative 1 and Action Alternative 2 would have fewer negative impacts on cultural resources than the No Action Alternative. Under the two action alternatives, water releases would occur and thus would provide protection for resources at very low elevations or presently protected by river sediment. However, resources could be subjected to additional visitation along the river due to the lower river levels. Adverse effects on historic properties would be resolved through the LTEMP PA or land management agency NHPA agreements. If no agreements exist, the normal NHPA Section 106 process would be undertaken.

No Action Alternative

Under the No Action Alternative, releases from Glen Canyon Dam could fall below levels analyzed under the LTEMP. The higher releases under the No Action Alternative could result in dead pool and associated declines in flows.

For the No Action Alternative, the median acreage of available sediment for windblown transport ranges from 1,643,222 square meters (m^2) at the 80th percentile to 1,575,186 m^2 at the 100th percentile. Lower river flows would result in the most sediment available in late 2024, again in late 2025, and again in late 2027 at the 100th percentile. Increases in available sediment are a beneficial impact of low river flows and could help cover archaeological sites with sediment.

If reduced releases result in a very low river level, then there would be increased access to previously inundated or buried precontact archaeological sites[15] between Lake Powell and Lake Mead. For sites with increased access, there may be deterioration of site integrity due to increased visitation or vandalism.

Flows, and therefore river levels, from Lake Mead downstream would initially be higher until Lake Mead drops to dead pool when they will drop precipitously. The drop in flows and river level may expose previously inundated cultural resources. These resources would then be exposed for a longer duration of time because it would be more difficult to increase flows back up to their previous levels.

Action Alternative 1

Under Action Alternative 1, releases from Lake Powell would be consistent with those approved and analyzed under the LTEMP while conditions permit. If insufficient water is available, releases would be coordinated to protect Lake Powell's 3,500-foot elevation. Projected releases below the LTEMP minimum for Action Alternative 1 would be less likely than for the No Action Alternative and would be designed to prevent dead pool at Lake Powell. Flows may be reduced but would still continue and thus protect more archaeological sites than the No Action Alternative.

[15] Precontact archaeological resources are those that predate Native American contact with Europeans.

Under Action Alternative 1, the median exposed sediment acreage ranges from 1,730,261 m^2 at the 80th percentile to 1,575,186 m^2 at the 100th percentile. Flows would be more evenly distributed under Action Alternative 1; therefore, sediment would be available for longer amounts of time and at more regular intervals than under the No Action Alternative.

As with the No Action Alternative, lower river levels due to changes in release volumes could also increase access to precontact archaeological sites between Lake Powell and Lake Mead.

Under Action Alternative 1, flows, and therefore river levels, from Lake Mead would be the same as under the No Action Alternative during 2023. They would drop in 2024–2025, and they would raise in 2026. Flows would be maintained for a longer duration of time than under the No Action Alternative as the minimum power pool level for Lake Mead would be maintained, preventing the lake from reaching dead pool.

Action Alternative 2

For Action Alternative 2, impacts on cultural resources along the river reach from Lake Powell to Lake Mead, as well as downstream from Lake Mead, would be the same as they would be for Action Alternative 1.

Cumulative Effects

Reclamation has identified one reasonably foreseeable future project that may, in conjunction with the proposed near-term Colorado River operations, contribute to cumulative effects on cultural resources; this project is the Glen Canyon Dam/Smallmouth Bass flow options. Reclamation is proposing to regulate flows from the Glen Canyon Dam to control smallmouth bass populations. All proposed flow options in the EA adhere to operational and regulatory constraints as outlined in the LTEMP FEIS and are unlikely to cause any additional impacts on archaeological sites in the reach from Glen Canyon Dam to Lake Mead; they should not contribute to cumulative impacts in conjunction with the proposed near-term Colorado River operations.

Issue 3: How would changes in operations affect TCPs and resources of concern to Native Americans?

Summary

Both Action Alternative 1 and Action Alternative 2 would have fewer impacts on sacred sites and TCPs than the No Action Alternative. Under the two action alternatives, visitor access to previously inundated sacred sites could increase to a lesser degree than under the No Action Alternative. Vegetation that may be considered elements of the river and canyon's TCPs would increase in Marble Canyon and the eastern Grand Canyon but decrease in the western Grand Canyon under the action alternatives. Any decline in the health of life within the Grand Canyon beyond those due to poor hydrologic conditions could have adverse effects on contributing elements of the TCP. Adverse effects on TCPs would be resolved through the LTEMP PA, other land management agency NHPA agreement documents, or the NHPA Section 106 process.

No Action Alternative

Under the No Action Alternative, visitor access to sacred sites below 3,496 feet at Lake Powell could increase; however, resources would be exposed in canyons that are difficult to access. At Lake

Mead, sacred sites could be more accessible to visitors above 1,000 feet in 2024 and above 895 feet in 2025–2026. Resources along the river could also be more accessible during low-flow times or if there is a complete drop in flows when less or no water is released from Lake Powell and/or Lake Mead. Habitat for nonnative plant species along the river is projected to increase in Marble Canyon, but not in Grand Canyon. Habitat for native plant species would be lost in both Marble and Grand Canyons (Butterfield and Palmquist 2023a). No flows could have significant adverse effects on fish that are a contributing element to the Colorado River TCP and to the health of the ecosystem as a whole.

Action Alternative 1

Under Action Alternative 1, visitor access to sacred sites at Lake Powell is not expected to greatly increase; this is because the lake level is likely to be at or above 3,500 feet through 2026. Lake Mead could drop below the previously analyzed 1,080 feet to 960 feet, which could increase visitor access to sacred sites located between 1,080 feet and 960 feet. Lower release volumes could result in increased accessibility to sacred sites along the river.

In general, Action Alternative 1 would result in increases in native and nonnative riparian vegetation in eastern Grand Canyon and Marble Canyon, respectively, when compared with the No Action Alternative. Action Alternative 1 would result in a decline in primarily nonnative species in the western Grand Canyon in comparison with the No Action Alternative (Butterfield and Palmquist 2023a). Any decline in the health of life within the Grand Canyon beyond those due to poor hydrologic conditions could have adverse effects on contributing elements of the TCP.

Action Alternative 2

For Action Alternative 2, impacts on TCPs and resources of concern to Native Americans would be the same as they would be for Action Alternative 1.

Cumulative Effects

Reclamation has identified one reasonably foreseeable future project that may, in conjunction with the proposed near-term Colorado River operations, contribute to cumulative effects on cultural resources; this project is the Glen Canyon Dam/Smallmouth Bass flow options. Reclamation is proposing to regulate flows from the Glen Canyon Dam to control smallmouth bass populations. All proposed flow options in the EA adhere to operational and regulatory constraints as outlined in the LTEMP FEIS; however, they may negatively impact characteristics of TCPs important to Native Americans. Adverse effects on TCPs, as historic properties, that result from the actions analyzed in this SEIS will be resolved through the LTEMP PA, other land management agency NHPA agreement documents, or the NHPA Section 106 process; therefore, the project should not contribute to cumulative impacts in conjunction with the proposed near-term Colorado River operations.

3.12 Paleontological Resources

3.12.1 Affected Environment

Paleontological resources (with some exceptions) include any fossilized remains, traces, or imprints of organisms preserved in or on the earth's crust. The Paleontological Resources Preservation Act (PRPA; 16 United States Code (USC) 470aaa-470aaa-11) and its implementation rule (43 CFR 49) require that the Department agencies preserve, manage, and protect paleontological resources on lands administered by the Bureau of Land Management, Reclamation, the NPS, and the Service and ensure that these federally owned resources are available for current and future generations to enjoy and study as part of America's national heritage.

The 2007 FEIS (Reclamation 2007) and the 2017 LTEMP FEIS do not address paleontological resources as a separate resource concern, although many of the potential impact issues related to reservoir levels and changes in river flows are analogous to those for cultural resources such as archaeological sites.

The NPS is primarily responsible for conservation of natural and cultural resources and the visitor experience (including recreation) at Lake Mead and Lake Powell. Reclamation manages water operations. Both agencies comply with the PRPA. For example, Lake Mead's General Management Plan Amendment/Low-Water Plan/EA of December 2018 anticipates NPS actions and resource protection at lake elevations above 950 feet.

Study Area

The fossil record near the Colorado River in this region can be traced back to 1.2 billion years ago. The thick sequence of overlying Paleozoic sedimentary strata preserve abundant fossil remains and traces of marine and terrestrial invertebrates, vertebrates, and plants. An extensive cave system developed into marine limestones preserve the remains of a diverse Pleistocene fauna (Santucci and Tweet 2021).

The study area for paleontological resources consists of the reaches of the Colorado River from Lake Powell to Imperial Dam and in the reach from Davis Dam to Imperial Dam. It includes the Colorado River channel from bank to bank and the backwaters, lakes, and marshes connected to the river. Special attention is paid to known and unknown resources in Lake Powell and Lake Mead. It is anticipated that the majority of potential resources and localities were submerged during the filling of the reservoirs. There is minimal data developed on potential paleontological resources in the deepwater zone of the reservoirs, but these resources may be the least vulnerable to effects from wave action and other disturbances. Resources in the operational zones are vulnerable and those above the fluctuating pool elevation are at risk for damage and disturbance by visitation.

Lake Powell and Glen Canyon Dam

Lake Powell is 186 miles long and contains 1,960 miles of shoreline, which includes 96 major side canyons. The landscape includes over 10,000 feet of sedimentary rocks that represent approximately 300 million years of earth history. This geologic history includes several mountain-building events, the formation of the supercontinent Pangea, multiple incursions of shallow seas onto the North

American continent, vast deserts with Sahara-like sand dunes, the rise and demise of the dinosaurs, unique igneous intrusions known as laccoliths, and the carving of the Colorado River system. Features in the sedimentary rock strata document marine, nearshore marine, fluvial, and eolian environments that have transformed the landscape of southeastern Utah through geologic time.

Current available GIS data for known paleontological sites are approximate locations and come from a variety of data sets and reports of varying quality and accuracy. GCNRA, IMR, and WASO are working on a 2-year project to compile and update existing data into one authoritative source. Based on current best available GIS paleontological data, at approximately 3,522 feet (current elevation as of February 16, 2023), 152 known paleontological sites are inundated.

Specific studies of the effects of inundation on paleontological locations are not known from Lake Powell. Anecdotal evidence from staff working in the field has resulted in documentation of sandstone becoming friable and crumbly after previous inundation and exposure. It is assumed that certain kinds of paleontological resources, especially trackways, found in softer bedrock such as sandstone, would be destroyed or severely impacted by the inundation and subsequent exposure resulting in loss of rock outcrop integrity. However, it is not known whether greater damage is caused only by inundation, or by repeated cycles of inundation and exposure. It is assumed that paleontological resources, including both fossils and trackways, would have similar impacts as those in archaeological sites from similar processes. The No Action Alternative would result in greater exposure of bedrock outcrops and greater exposure of previously inundated paleontology sites to wet/dry cycling thus has the potential to result in greater numbers of paleontology sites being subject erosion and damage as a result of exposure.

Erosion is the primary agent that exposes paleontological resources on the surface. Reclamation manages a significant amount of land along the Colorado River corridor, resulting in higher-than-normal erosional rates and increased potential for the exposure of paleontological resources. From a scientific perspective, elevated erosion levels along waterways provide an opportunity in that fossil resources may be exposed more quickly, allowing for more frequent discoveries. Yet from a management perspective, these elevated erosion levels present the concern for elevated levels of loss potential (Bonde and Slaughter 2020).

The GCNRA has one of the most extensive exposures of Mesozoic era rocks of any NPS unit, providing exceptional documentation of ecosystems and paleoclimates from approximately 252 million to 66 million years ago. Marine fossils are common in Paleozoic limestones, while dinosaur tracks are found in the terrestrial Mesozoic units. Pollen extracted from dung and packrat middens have provided evidence for the ecology and climate during the more recent Quaternary period. The NPS maintains an inventory and monitoring database for known fossil sites in the park. Natural degradation and fossil theft remain a concern for resource managers.

Because of Glen Canyon Dam, sediment is continuously deposited in Lake Powell. Sediment deposition has impacted several locations in the lake, including paleontological sites. Sediment deposition may prevent exposure of paleontological resources (Graham 2016).

Lake Mead and Hoover Dam

The LMNRA does not have a comprehensive paleontological inventory of locations, but there are known and likely many unknown submerged paleontological resources. There are fossil sites that are exposed at recent lake levels and are subject to disturbance from fluctuating water levels and visitor impacts. Lake Mead has formations with high fossil potential including the Miocene Horse Spring Formation and the Muddy Creek Formation, and the Pliocene and Pleistocene river gravels. Where these formations outcrop along the lake are now more spatially exposed, providing a high chance to find new fossil localities with them. Increased exposure of fossil bearing geological formations around the lake would be anticipated with lower lake levels and exposed shorelines.[16]

3.12.2 Environmental Consequences

Methodology

There was no formal analysis of effects on paleontological resources in developing the 2007 FEIS. Methods to qualitatively assess the potential for effects on paleontological resources use a proxy based on lake elevations developed for analyzing the potential for impacts on cultural resources. For cultural resources in the 2007 FEIS, the 10th percentile as the "worst-case scenario" for Lake Powell was used to assess the impacts for each alternative (Reclamation 2007). Similar to the cultural resource analysis in this SEIS, the lowest Lake Powell water elevation accounted for was 3,496 feet. The effects of anticipated lake elevations below 3,496 feet re addressed in this current analysis. For Lake Mead, an elevation of 1,080 feet was used as lowest elevation (Reclamation 2007). In this analysis, elevations below 1,080 feet will be assessed also using the 10th percentile as the "worst-case scenario." For resources along the river, the potential for impacts within the river reaches were assessed by comparing anticipated flows with the historical minimum and maximum river flows.

The USGS has conducted a study of the availability of windblow sediment by alternative in the reach between Glen Canyon Dam and Bright Angel Creek (Kasprak et al. 2023). Windblown (or aeolian) sediment can be important for assessing the potential exposure of paleontological resources. Dry sediment is transported by the wind from the riverbed to locations where paleontological resources may occur along the river where they cover and protect the sites. The results of this study are discussed below.

Impact Analysis Area

The impact analysis area for paleontological resources consists of the reaches of the Colorado River from Lake Powell to Imperial Dam and in the reach from Davis Dam to Imperial Dam. It includes the Colorado River channel from bank to bank and the backwaters, lakes, and marshes connected to the river.

[16] Chris Nycz, Cultural Resource Manager, LMNRA, email to Kevin Doyle, EMPSi, resource lead on February 17, 2023, regarding paleontological resources at LMNRA.

Assumptions

The assumptions for the following analysis are:

- Impacts on paleontological resources can be characterized based on projected lake elevations and river flows.
- The impact analysis area includes known paleontological resources that are being exposed and rock units that are sensitive for the presence of scientifically important paleontological resources.
- Specific paleontological locations are not discussed in this analysis, but the level of information available is assumed to be sufficient for this broad-based analysis.
- The exposure of paleontological resources may lead to the discovery of scientifically important fossils, however the process and practical means of recovering paleontological resources within the reservoirs or associated with the Colorado River channel would be limited.
- Landforms with a higher degree of slope experience increased impacts from wave action erosion over low slope areas.

Impact Indicators

Impact indicators for this analysis are:

- Projected lower lake elevations that may expose resources to damage from wave action, wet/dry cycling of fluctuating water levels, increased visitation, and unauthorized collection or vandalism
- Projected changes in river flows that are not within the historical minimum and maximum that may contribute to erosion
- Availability of windblown sediments to protect paleontological localities or exposed fossils

Issue 1: How would changes in lake elevations from water releases from Lake Mead and from equalizing/balancing Lake Mead and Lake Powell affect previously submerged paleontological resources, as well as those at the lake margins?

Summary

All the alternatives would result in lake elevations which may further expose resources to damage from wave action, wet-dry cycling of fluctuating water levels, increase visitation and unauthorized collection or vandalism. However, Action Alternative 1 and Action Alternative 2 would maintain power pools that would reduce the potential for impacts on paleontological resources from the lowest lake levels. Implementation of the PRPA by both NPS and Reclamation provides protections and fines for disturbances to paleontological resources.

No Action Alternative

Under the No Action Alternative, Lake Powell pool elevations for the 10th percentile is 3,450 feet. In 2025 through 2026, pool elevations may dip below 3,496 feet to 3,425 feet with an estimated additional exposed shoreline of 28,000 acres. An additional 25–43 known paleontological sites would be exposed. Newly exposed resources below 3,496 feet may be exposed to increased visitation. Visitor impacts could result from unauthorized driving off approved roads, visitor-created boat launch areas, visitor-created walking trails on newly exposed land, and unauthorized collecting and vandalism. Negative impacts from wave action and wet/dry cycles may be seen on newly exposed resources. Note that these site numbers do not capture the entirety of the paleontological resources, since many areas have not had assessments.

Lake Mead pool elevations are currently below 1,080 feet and are projected to dip to approximately 1,000 feet by the end of 2024, with an estimated additional exposed shoreline of 94,350 acres. The 10th-percentile scenario for Lake Mead between 2025 and 2026 is a pool level of almost dead pool at 895 feet, potentially exposing paleontological resources. These locations may be affected by wave action at lake margins, wet/dry cycles, and likely increased visitation.

Action Alternative 1

Under Action Alternative 1, Lake Powell pool elevations may dip below the minimum power pool of 3,490 feet in 2024; however, the minimum power pool elevation of 3,500 feet will be protected under extraordinary circumstances. Pool elevations are projected to be at or above 3,500 feet through 2025–2026. Therefore, potential impacts on exposed paleontological resources at Lake Powell for Reservoir Operations Modifications would be less than those anticipated under the No Action Alternative.

For Lake Mead, pool elevations are projected to be as low as 925 feet in 2025 but up above 950 feet in 2026; however, the 950 feet power pool will be protected except under extraordinary circumstances. Because the power pool level of 950 feet would be maintained, impacts on paleontological resources under Action Alternative 1 would be less than those under the No Action Alternative.

Action Alternative 2

Potential impacts on paleontological resources at Lake Powell and Lake Mead for Action Alternative 2 would be the same as for Action Alternative 1.

Cumulative Effects

Reclamation is proposing to regulate flows from the Glen Canyon Dam to control smallmouth bass populations. The proposed releases are within the previously approved flows under the No Action Alternative and are unlikely to cause any additional impacts on paleontological resources. Cumulatively, negative impacts on paleontological resources are anticipated in the near and long term from each of the proposed alternatives associated with the drop in lake levels.

Issue 2: How would changes in river flow from water releases from Lake Mead and from equalizing/balancing Lake Mead and Lake Powell affect paleontological resources along the river?

Summary

All the alternatives would result in releases that may lower river levels and increase visitor access and potential impacts on paleontological resources. However, Action Alternative 1 and Action Alternative 2 would more evenly distribute flows and reduce the potential for impacts on paleontological resources from fluctuating river levels, Sediment would be available for longer amounts of time and at more regular intervals than under the No Action Alternative.

No Action Alternative

Under the No Action Alternative, releases from Glen Canyon Dam from Lake Powell may fall below levels approved for LTEMP. Impacts on paleontological resources may occur from changes in erosion or depositional processes between Lake Powell and Lake Mead.

Median acreages of available sediment for windblown transport for the No Action Alternative ranges from 1,643,222 m^2 at the 80th percentile to 1,575,186 m^2at the 100th percentile. Lower river flows will result in the most sediment available in late 2024, again in late 2025, and again in late 2027 at the 100th percentile. Increases in available sediment are a beneficial impact of low river flows by reducing the potential exposures of paleontological resources.

If reduced releases result in low river level, they may increase visitor access to previously inundated and/or buried paleontological resources between Lake Powell and Lake Mead. For locations with increased access, there may be new deterioration of paleontological resource because of increased visitation.

Action Alternative 1

Under Action Alternative 1, releases from Lake Powell would be consistent with those approved and analyzed under the LTEMP while conditions permit. If insufficient water is available, releases would be coordinated to protect the minimum power pool elevation of 3,500 feet elevation in Lake Powell. Under Action Alternative 1, median exposed sediment acreage ranges from 1,730,261 m^2 at the 80th percentile to 1,575,186 m^2 at the 100th percentile. As flows are more evenly distributed under Action Alternative 1, sediment is available for longer amounts of time and at more regular intervals than under the No Action Alternative, thus reducing the potential for exposure of previously inundated paleontological resources.

As with the No Action Alternative, lower river levels due to changes in release volumes may also increase access to paleontological resources between Lake Powell and Lake Mead; for locations with increased access, there may be new deterioration of paleontological resources because of increased visitation.

Action Alternative 2

Impacts on paleontological resources along the river reach from Lake Powell to Lake Mead for Action Alternative 2 would be the same as for Action Alternative 1.

Cumulative Effects

The proposed releases are within the previously approved flows under the No Action Alternative and are unlikely to cause any additional impacts on paleontological resources. Cumulatively, negative impacts on paleontological resources are anticipated in the near and long term from each of the proposed alternatives from associated with fluctuating water levels, increase visitation and unauthorized collection or vandalism. Violations of the PRPA by visitors can result in punishments under law.

3.13 Biological Resources

3.13.1 Affected Environment

In order to supplement 2007 FEIS (Reclamation 2007), this section provides a brief summary of a more comprehensive description of the affected environment in the 2007 document, supplementing as necessary to include changes that have occurred since 2007. For additional information, see the 2007 FEIS (Reclamation 2007), the 2016 LTEMP FEIS (Reclamation and NPS 2016), and the LCR MSCP Habitat Conservation Plan (HCP; Reclamation 2004), which are incorporated by reference.

The elevation gradient, soil types, and flow characteristics along the Colorado River corridor create diverse vegetation and habitat communities that support plants, wildlife, and special status species (Reclamation 2007). Vegetation along the Colorado River is heavily influenced by flow characteristics, which are manipulated through dam operations (Reclamation and NPS 2016). This manipulation of flow characteristics can alter shoreline sand bars and vegetation communities along the Colorado River corridor, thereby impacting plants, wildlife, and special status species.

The vegetation, wildlife, and special status species typical of each section are outlined below, based on the 2007 FEIS; the 2016 LTEMP FEIS (Reclamation and NPS 2016); the LCR MSCP HCP (Reclamation 2004); and a query of BLM sensitive species in the natural heritage databases for Utah (BLM 2018), Arizona (BLM 2017b), Nevada (BLM 2017a), and California (BLM 2014).

Vegetation

Circumstances that have resulted in substantial changes to vegetation beyond what was analyzed in the 2007 FEIS in the overall biological resources analysis area include: drought conditions, low inflows, and historically low water levels; the introduction of the tamarisk leaf beetle (*Diorhabda* spp.); changes in vegetation community composition below Glen Canyon Dam due to changes in river flow, particularly in alluvial areas; and the creation of riparian habitat in conservation areas below Hoover Dam associated with actions conducted by the LCR MSCP. These changes are described below under their respective geographic analysis area.

Lake Powell

As described in the 2007 FEIS, riparian vegetation around Lake Powell is extremely restricted because of the desert terrain that extends directly to the water's edge, and the continuously fluctuating lake elevations. Fluctuations in lake elevations have resulted in standing water and backwater pools in the side canyons of Lake Powell where riparian vegetation has become established. Dominant plants found in these canyons include Fremont cottonwood (*Populus fremontii*), tamarisk (*Tamarix* spp.), and cattail (*Typha* sp.).

Lake Powell is currently operating at a historically low water level due to prolonged drought. Since 2007, the increase in acreage of exposed shoreline has increased Russian thistle (*Salsola* spp.) and tamarisk establishment. Currently, tamarisk and Russian thistle are the dominant vegetation type along the shores of Lake Powell. Dense stands of tamarisk displace native plants, degrade wildlife habitat, reduce livestock forage, limit human access, interfere with the natural fluvial process, and increase the risk of severe wildfires. In addition to terrestrial impacts, tamarisk impacts aquatic systems by eliminating side channel and backwater habitats that provide critical spawning and nursery habitat for native fish and by trapping sediment (NPS 2023l). Tamarisk changes the ecology and hydrology of riparian systems. It has one of the highest evapotranspiration rates of any riparian shrub, removing water from the soil and releasing it through the leaves. Water loss caused by tamarisk can range to 13 afy.

Russian thistle easily takes root in disturbed or bare ground, moving in before native species can establish. Drought conditions like those experienced in recent years only promote the plant's proliferation. The dryness hinders the growth of native species, while the Russian thistle seed requires very little moisture to germinate and grow where native species otherwise would have. This can have deleterious effects on natural ecological functioning and increase the wildfire risk (NPS 2023l).

GCNRA has many springs and seeps that are common in alcoves along Glen Canyon walls, and water pockets located in canyons and uplands. These areas are recognized for their significance as wetland habitats and as unique ecosystems within the desert. These seeps support hanging gardens, which are a specialized vegetation community (Welsh et al. 1987). The water sources that support hanging gardens originate from natural springs and seeps within the Navajo Sandstone formation and are independent of Lake Powell. Livestock grazing is allowed at GCNRA, with the Bureau of Land Management administering the grazing permits. Vegetation monitoring does occur in the upland areas of the recreation area, but no studies have been conducted on the riparian habitat along the lakeshore.

Glen Canyon Dam to Lake Mead

Vegetation along the reach of the Colorado River corridor from Glen Canyon Dam to Lake Mead is affected by the peak magnitudes, daily fluctuations, and seasonal pattern of river flows, and most evidence indicates that riparian vegetation composition, structure, distribution, and function are closely tied to ongoing Glen Canyon Dam operations (Reclamation and NPS 2016).

Existing vegetation communities for this reach are described in detail in the LTEMP FEIS (Reclamation and NPS 2016), which provides a framework for managing Glen Canyon Dam operations and experimental actions over a 20-year period. As described in the LTEMP FEIS, terrestrial plant communities along the Colorado River from Glen Canyon Dam to Lake Mead are highly diverse due to great variations in landforms, geologic features, and physical characteristics such as topography, elevation, and aspect. Sediment deposits that can support vegetation occur along channel margins, on banks in the pools upstream from channel constrictions, on the boulder dominated debris fans, and as sandbars in eddies downstream from debris fans (Palmquist et al. 2018). Plant communities present along the river have developed through associations of species with similar responses to moisture gradients, tolerance to water stress, and modes of reproduction. Such species associations occur on geomorphic surfaces of debris fan-eddy complexes, such as reattachment bars and separation bars, as well as on channel margins between these complexes, and respond dynamically to changes in flow characteristics. Because of historical patterns of dam releases, communities below the 25,000-cfs elevation on these surfaces differ somewhat from those above that level. Seven plant community types have been identified as occurring on these geomorphic surfaces and are listed in Table 3.6-1 of the LTEMP EIS (Reclamation and NPS 2016).

The distribution of species within the riparian zone generally follows a hydrologic gradient, with obligate wetland species at the water's edge and facultative and upland species farther from the shoreline. Vegetation associated with the riparian zone is a mix of native and nonnative woody and herbaceous vegetation that reflects the pre- and post-dam habitats available for plant species The current vegetation is still comprised of many of the native species historically documented as occurring along the river, including Emory's baccharis (*Baccharis emoryi*), mule fat (*Baccharis salicifolia*), spiny chloracantha (*Chloracantha spinosa*), alkali goldenbush (*Isocoma acradenia*), arrowweed (*Pluchea sericea*), coyote willow (*Salix exigua*), and sand dropseed (*Sporobolus cryptandrus*). Other common native species include Arizona threeawn (*Aristida arizonica*), white sagebrush (*Artemisia ludoviciana*), desert broom (*Baccharis sarothroides*), horsetail (*Equisetum x ferrissii*), western goldentop (*Euthamia occidentalis*), and mesa dropseed (*Sporobolus flexuosus*). Some nonnative species are dominant components of this system as well, including tamarisk (*Tamarix* spp.), creeping bentgrass (*Agrostis stolonifera*), camelthorn (*Alhagi maurorum*), annual *Bromus* spp., and bermudagrass (*Cynodon dactylon*) (Palmquist et al. 2018).

As described in the LTEMP EIS (Reclamation and NPS 2016), vegetation zones along the river reflect the frequency of inundation and disturbance. The fluctuating zone supports flood-tolerant marsh species, such as sedges, rushes, cattail, horsetail, and common reed. These species occupy return-current channels and successional backwaters that are inundated daily for at least part of the year (i.e., up to the elevation of the average annual daily maximum discharge of about 20,000 cfs). As depicted in Figure 3.6-1 of the LTEMP EIS (Reclamation and NPS 2016), vegetation in the fluctuating and new high water zones are greatly influenced by river flow and dam operations. The new high water zone, inundated by flows up to 45,000 cfs, supports woody riparian species, many herbaceous-obligate riparian species (e.g., *Carex* spp., *Juncus* spp., *Equisetum* spp., *Phragmites australis*, and *Typha* spp.) with bunchgrasses such as sand dropseed, and shrubs such as spiny aster at upper elevations.

The dominant woody species of the Glen Canyon and Grand Canyon new high water zone scrub communities include tamarisk, coyote willow, arrowweed, and seepwillow (*Baccharis* spp.), along with desert broom downstream from RM 162. Wide, alluvial reaches have greater vegetation cover than narrow, confined reaches. The old high water zone, above 45,000 cfs to approximately 200,000 cfs, supports pre-dam drought-tolerant riparian species found in riparian and upland habitats, such as honey mesquite, catclaw acacia, netleaf hackberry, Apache plume, New Mexico olive, and mountain pepperweed (*Lepidium montanum*), along with desert species such as Mormon tea (*Ephedra* spp.), prickly pear (*Opuntia* spp.), creosote, ocotillo, and brittlebush. Mortality of old high water zone plants is occurring. Some species such as mesquite and hackberry are no longer recruiting in this zone because of the lack of sufficiently high flows and nutrient-rich sediment inputs; however, mesquite and catclaw acacia are now recruiting in the new high water zone. Because flows do not exceed 45,000 cfs with normal dam operations, the upper margins of this zone are moving downslope, resulting in a narrowing of the zone. Desert species occupy pre-dam flood terraces and windblown sand deposits above the old high water zone (Reclamation and NPS 2016).

Riparian vegetation communities can be affected by dam operations through scouring and erosion during high flows, drowning, burial by new sediments, and reductions in soil moisture levels; consistent availability of water at low elevations (e.g., below 25,000 cfs) from elevated base flows can promote vegetation growth. Responses of riparian vegetation are affected by the timing, frequency, duration, and magnitude of the river's hydrology, as well as the variability between years and sequencing of flows (Palmquist et al. 2018). Additional factors related to flow that influence riparian vegetation include characteristics of deposited sediments (such as water-holding capacity, aeration, and nutrient levels), depth to groundwater, and anoxia in the root zone. The export of sediments (particularly silts and clays and organic matter) coarsened substrates, affected nutrient concentrations, and reduced opportunities for subsequent recruitment of tamarisk and native shrubs such as coyote willow and Emory seepwillow (Reclamation and NPS 2016).

The population of Goodding's willow along the river below Glen Canyon Dam appears to have been affected by the reduction in flood flows on upper riparian terraces. It has been in decline and either no longer occurs at or does not reproduce at two-thirds of the sites where it previously existed (Reclamation and NPS 2016). Restoration of Goodding's willow and several other native species has been a focus of revegetation efforts. The lack of flood and flow attenuation parameters, which prevent seedling establishment, have reduced Goodding's willow and Fremont cottonwood (*Populus fremontii*) within the canyon and may influence the invasion of resultant open areas by tamarisk (Mortenson et al. 2008). In addition, recruitment of these species along the river is nearly eliminated each year by beavers (*Castor canadensis*) foraging on seedlings, and very few Fremont cottonwood occur along the river below the dam (Reclamation and NPS 2016).

A number of nonnative plant species, many of which are invasive species, occur throughout the riparian zone. Among the most common species are tamarisk, camelthorn, Russian thistle (*Salsola tragus*), ripgut brome (*Bromus diandrus*), red or foxtail brome (*Bromus rubens*), cheatgrass (Bromus tectorum), yellow sweetclover (*Melilotus officinalis*), spiny sow thistle (Sonchus asper), Ravenna grass (*Saccharum ravennae*), perennial peppergrass (*Lepidium latifolium*), and Bermuda grass (*Cynodon dactylon*) (Reclamation and NPS 2016). Tamarisk has long been the most prominent of these invasive species. Mortenson et al. (2012) showed how changes in the flow regime resulted in successive recruitment of tamarisk to lower river stages.

The tamarisk leaf beetle has had a marked impact on the ecology of riparian zones in Glen, Marble, and Grand Canyons in recent years. The beetle causes early and repeated defoliation of tamarisk during the summer months, which may eventually result in mortality after several successive years of defoliation. The long-term effects of the tamarisk leaf beetle and splendid tamarisk weevil on tamarisk abundance and distribution in Glen and Grand Canyons are currently not known; however, plant communities in which tamarisk is currently a dominant species would likely undergo compositional change (Reclamation and NPS 2016). Both native and nonnative plant species may become established on sites of tamarisk mortality, although native species establishment may be slow, and future community composition and habitat characteristics would depend on a variety of site-specific factors, including site hydrology and microclimate, changes in nutrient dynamics, available seed sources, and active restoration efforts (Reclamation and NPS 2016).

During development of the LTEMP FEIS, the effects of dam operations on riparian vegetation health along the river corridor were evaluated, and modeling results suggested long-term declines, particularly in native plant communities. With operational flows limited to less than 45,000 cfs, the overall extent and health of the riparian areas in GCNP have and would continue to be altered, and nonnative vegetation and monoculture species would likely increase. Therefore, a 20-year experimental riparian-restoration project was developed by the NPS and other agencies, as designated in the environmental commitments of the LTEMP ROD. There are four specific vegetation issues influenced by dam operations that emerged in the LTEMP FEIS that the restoration projects specifically seek to address: 1) encroachment of vegetation on sandbars, 2) decrease in native plant species, 3) erosion of archaeological resources, and 4) narrowing and loss of plants in the old high water zone (Reclamation and NPS 2016). Implementation of HFEs under the LTEMP have influenced riparian vegetation in this reach. Since 2012, five HFEs have been conducted; none have been conducted since 2018.

Lake Mead

The highest concentration of vegetated habitat associated with Lake Mead is found in the Colorado and Virgin River deltas. Fluctuating lake elevations influence the shoreline vegetation. Riparian vegetation that does develop within the range of Lake Mead elevation fluctuations is temporary, as fluctuating lake elevations either de-water or inundate these areas through time. Linear riparian woodlands may be present along the shoreline of the Lake Mead delta following high water flows and associated sediment deposition and exposure. The sediment deposition and the associated growth of riparian vegetation at the Lake Mead delta has occurred for decades. However, riparian vegetation is historically thought to be sparse, even along much of the historical Colorado River corridor that Lake Mead submerged, and much of the existing shoreline is sparsely vegetated (Engel et al. 2014).

Water levels at Lake Mead have declined to some of the lowest elevations for an extended period of time due to prolonged drought. Decreasing water levels reduce the lake perimeter while increasing the amount of shoreline area relative to the unsubmerged amount when the lake is at full pool. The consistent decline in water level since 1998 has prevented the establishment of a stable riparian community. The drawdown of Lake Mead from 1998 to 2011 reduced the lake's perimeter by more than 248 miles (400 km) while exposing more than 61,776 acres (25,000 ha) of formerly submerged land. Engel et al. 2014 observed that, consistent with previous research, the abundance of the tamarisk declined with increasing surface age. Conversely, the cover of native species was greatest overall on older surfaces across sites. Early successional native perennial species colonized the 13-year-old surface. While Lake Mead's drawdown might be viewed negatively from a perspective of maintaining full pool water storage, it has re-exposed a vast area of new terrestrial habitat increasingly colonized by native species as invasive species abundance declines through time (Engel et al. 2014).

The vegetation at Lake Mead has also been influenced by defoliation from the tamarisk leaf beetle. Beetles were released along the Virgin River in St. George, Utah, in 2006, and widespread defoliation of tamarisk was first observed in St. George in 2008. The area of tamarisk defoliation on the Virgin River expanded downstream annually, encompassing the entire stretch of the Virgin River to Lake Mead, Nevada, by the end of the breeding season in 2011.

Hoover Dam to SIB

Vegetation for this reach is described in detail in the LCR MSCP HCP (Reclamation 2004). Fourteen land cover types are described in the LCR MSCP planning area. Five woody riparian types are divided into multiple structural types, and the marsh land cover type is divided into seven compositional types based on plant composition and vegetation structure. Aquatic land cover types include river, reservoir, and backwater. A summary of the land cover types and their characteristics, found from Lake Mead to the SIB, is provided in Table 3.8-1 of the 2007 FEIS and in more detail in Section 3.4 of the LCR MSCP HCP (Reclamation 2004).

Since released in 2006, tamarisk beetles have continued to spread downstream from Lake Mead along the LCR, and by 2019, large beetle populations were detected along the Imperial stretch of the LCR. In 2020, tamarisk beetles were present, and defoliation was documented in or around all LCR MSCP study areas (Reclamation 2021d).

The LCR MSCP has adopted a habitat-based approach to the conservation of covered species. Riparian communities identified in the LCR MSCP HCP as covered species habitat include cottonwood-willow, honey mesquite, marsh, and backwater land cover types. The HCP requires the creation of over 8,100 acres (3,277 ha) of various land cover types to provide habitat for targeted LCR MSCP covered species. Since 2006, over 3,000,000 cottonwood and willow trees have been established within conservation areas in addition to a host of other varieties such as honey mesquite, wetlands plants, and salt grass plugs. As of 2021, a total of 4,274 acres of cottonwood-willow, 2,046 acres of mesquite, 362 acres of marsh, and 158 acres of backwater have been restored and are managed by the LCR MSCP (LCR MSCP 2022).

Wildlife

Lake Powell

Lake Powell and its associated upland habitat supports a wide variety of wildlife species. The limited riparian habitat around Lake Powell is a highly valuable resource for wildlife species dependent on riparian habitat in this portion of the analysis area. The 2007 FEIS lists common amphibians (e.g., Canyon tree frog [*Hyla arenicolor*]), aquatic and riparian birds (e.g., American wigeon [*Anas americana*]), and mammal species (e.g., beavers [*Castor canadensis*]) found in Lake Powell and its associated upland habitat (Reclamation 2007).

Lake Powell is the second-largest impoundment on the Colorado River, and it provides habitat for primarily lacustrine fish species. However, inflows to the lake also provide riverine habitat for various fish species. The fish community in Lake Powell is dominated by nonnative species, with a total of 14 nonnative species (Reclamation 2007). Recreational fishing is an important industry in the Colorado River, and Lake Powell supports a sport fishery for striped bass (*Morone saxatilis*), largemouth bass (*Micropterus salmoides*), and smallmouth bass (*Micropterus dolomieui*). Additionally, management actions in this reservoir have also introduced nonnative forage fish to support this sport fishery.

Deltaic deposits have formed in the inflows of the Colorado and San Juan Rivers and have become exposed with receding lake levels in the past 20 years. These rivers have carved new channels into the deposits and expanded riparian areas and the riverine habitat of fish, including native and nonnative species. In the San Juan River inflow, riverine habitat has been expanded by about 30 miles (48 km) and a 20-foot (6-meter) waterfall has formed at the upper end that now blocks upstream movement by fish.

At the time of the FEIS (Reclamation 2007), it was unclear whether zebra mussels or quagga mussels were established in Lake Powell. However, quagga mussels were discovered in 2012 and sampling in subsequent years (2014–2019) indicated that this species has continued to spread throughout the reservoir (Utah Department of Natural Resources 2021).

Glen Canyon Dam to Lake Mead

The terrestrial habitat from Glen Canyon Dam to Lake Mead is predominantly canyon habitat, including portions of GCNRA and GCNP. Canyon habitat provides a variety of vegetation types that support upland and obligate riparian species. Riparian habitat is more common along this stretch of the Colorado River compared with Lake Powell. Vegetation in this section is dominated by the invasive tamarisk plant. However, the introduction of the tamarisk leaf beetle has had recent impacts along this stretch of the river, changing community composition and reducing tamarisk cover. The beetle will likely play a large role in habitat composition over the next several years (Reclamation and NPS 2016). Many species of amphibians (e.g., canyon tree frog [*Hyla arenicolor*], red-spotted toad [*Bufo punctatus*], and Woodhouse's toad [*Bufo woodhousii*]), aquatic and riparian birds (e.g., yellow warbler [*Dendroica petechia*], great blue heron [*Ardea herodias*], and osprey [*Pandion haliaetus*]), and mammal species (e.g., coyote [*Canis latrans*], desert bighorn sheep [*Ovis canadensis nelsoni*], muskrat [*Ondatra canadensis*], and American beaver [*Castor canadensis*]) are found in this portion of the analysis area and its associated upland habitat (Reclamation 2007; Holm et al. 2023).

For aquatic species, this section includes the Colorado River below Glen Canyon Dam through Grand Canyon for approximately 290 miles (466 km) and the Lake Mead inflow for an additional 25 miles (40 km). A large rapid has formed near Pearce Ferry (RM 280) that serves as a partial barrier to upstream fish movement. The entire reach from the dam to Lake Mead includes approximately 18 species of nonnative fish and 5 native species (Valdez and Carothers 1998). A Blue Ribbon trout fishery exists in the 15 miles (24 km) of river below Glen Canyon Dam (Lees Ferry), consisting of rainbow trout, although in recent years brown trout populations have been increasing. Smallmouth bass, which are an invasive and predatory fish have been detected below Glen Canyon Dam, creating a need to prevent establishment before they impact native fish. Reclamation is pursuing an EA that would allow them to use dam operations to reduce the temperature of the water to prevent establishment of smallmouth bass. The Lake Mead inflow is characterized by deltaic sediments exposed with the declining lake level, through which the river has carved a channel. A large rapid has formed near Pearce Ferry (RM 280) that serves as a partial barrier to upstream fish movement.

Quagga mussels are not considered an issue in this section due to the riverine habitat (Reclamation 2007). However, the New Zealand mudsnail (*Potamopyrgus antipodarum*) has recently been documented in the Colorado River (Cross et al. 2010), downstream of Glen Canyon Dam.

Lake Mead

Similar to Lake Powell, Lake Mead and its associated upland habitat supports a wide variety of wildlife species. Riparian habitat in the Lake Mead section is generally limited to the Lake Mead and Virgin River deltas. These areas undergo frequent water level fluctuations, which results in fluctuating riparian habitat availability. The 2007 FEIS refers to the Lake Mead section of the analysis area as having similar common wildlife species as the Lake Powell section and the Glen Canyon Dam to Lake Mead section of the analysis area (Reclamation 2007).

With declining lake elevations in the last 20 years, the Colorado and Virgin Rivers have expanded as river channels carved into the deltaic sediment deposits. The Colorado River inflow has expanded in length about 40 miles (64 kilometers) from full pool elevation at Separation Canyon downstream to Pearce Ferry and the Virgin River has expanded about 20 miles (32 kilometers), providing additional riverine habitat for aquatic species. Lake Mead provides lacustrine habitat for nonnative and native fish species. The lake supports a sport fishery for primarily striped bass, largemouth bass, crappie, bluegill, and catfish.

Both Lake Mead and Lake Mohave have experienced algal blooms since the early 2000s. These blooms are the result of nutrients within the Colorado River generally derived from decaying vegetation in the largely undeveloped watershed, as well as nutrients from the Virgin River, Muddy River and Las Vegas Wash. These nutrients arrive in the form of treated wastewater, urban runoff, and agricultural runoff. Lower lake levels affect lake nutrients as well as nutrient dynamics. These in turn affect the amounts and location of algae produced in these reservoirs. Starting in the year 2000, the wastewater treatment plants along Las Vegas Wash have enhanced their phosphorus removal improving water quality and reducing the potential for algal blooms. Monitoring has revealed that these blooms include blue-green algae, which bloomed in large amounts in 2011–2015, and again in recent years since 2020. Blue-green algae produces a toxin called microcystin that can cause health issues with people and wildlife. The effects of these algal blooms on fish and wildlife are not well understood, and monitoring will need to be continued to better understand the relationship between reservoir elevations, algal blooms, and effects on fish populations in both Lakes Mead and Mohave.

In 2007, quagga mussels were documented in Lake Mead (Reclamation 2007), and they persist there.

Hoover Dam to the SIB

The lower section of the Colorado River supports diverse habitat types, which in turn supports a variety of wildlife species. Restoration activities described in the LCR MSCP have increased the amount of desirable habitat communities, including riparian vegetation, marsh habitat, backwater habitat, and wetlands (Reclamation 2004). The 2007 FEIS lists common amphibians (e.g., bullfrog [*Rana catesbeiana*]), aquatic and riparian birds (e.g., avocet [*Recurvirostra americana*]), and mammal species (e.g., bobcat [*Felis rufus*]) found in this portion of the analysis area and its associated upland habitat (Reclamation 2007).

Fish habitat exists in this section where surface water is perennial. This section is dominated by nonnative species (Reclamation 2007).

Since Quagga mussel life history includes a pelagic larval stage, it is reasonable to assume that these mussels are present below Hoover Dam in any areas where suitable habitat is present.

Special Status Species

Special status species include federally threatened, endangered, or proposed species as well as species on the state BLM sensitive species lists for Utah (BLM 2018), Arizona (BLM 2017b), Nevada (BLM 2017a), and California (BLM 2014). Species on these lists were queried with the state natural heritage databases for each of the four states to determine which species had records in the analysis area. Only those species identified as present in the natural heritage databases were included in this analysis. The resulting data were used to populate **Table 3-28** and **Table 3-29**.

See the vegetation and general wildlife sections for a description of habitat within each of the four sections of the analysis area, as these descriptions are not repeated below. For habitat requirements for the species in **Table 3-28** and **Table 3-29**, see NatureServe Explorer (2023), which is incorporated by reference. Information pertaining to Endangered Species Act (ESA)-listed species is still being drafted in the biological assessment. Updated information will be incorporated into the final SEIS when it is available.

Lake Powell

Table 3-28 lists all federally threatened, endangered, or proposed species and whether they occupy Lake Powell. **Table 3-29** lists all non-ESA-listed special status species and whether they occupy Lake Powell.

In the Colorado River inflow to Lake Powell, Colorado pikeminnow are found as larvae and age-0 fish that are transported from upstream, but a population has not become established in the inflow. Periodically, large adult Colorado pikeminnow are found in the inflow as transient members of upstream populations in the Green and Upper Colorado Rivers (Service 2022). Razorback suckers are also found in the Colorado River inflow of Lake Powell. These fish are usually found as adults from upstream populations, and there are some fish that move across Lake Powell from the San Juan inflow (Service 2018a). Excess numbers of bonytail from the Wahweap State Fish Hatchery (Utah) are released periodically into Lake Powell, but they are not part of a formal stocking plan (Smith 2022).

Table 3-28
Federally Listed Species potentially affected by the Alternatives

Common Name	Scientific Name	Listing Status	Location			
			Lake Powell	Glen Canyon Dam to Lake Mead	Lake Mead	Hoover Dam to the SIB
Fish						
Bonytail	*Gila elegans*	Endangered BLM NV	X (rare, stocked)			X (stocked)
Colorado pikeminnow	*Ptychocheilus lucius*	Endangered	X (rare in lake, common in inflows)			
Humpback chub	*Gila cypha*	Threatened		X	X (new population below full pool elevation in Colorado River Inflow)	

Common Name	Scientific Name	Listing Status	Location			
			Lake Powell	Glen Canyon Dam to Lake Mead	Lake Mead	Hoover Dam to the SIB
Razorback sucker	*Xyrauchen texanus*	Endangered BLM NV	X	X (currently present downstream of Lava Falls Rapid)	X	X
Birds						
Southwestern willow flycatcher	*Empidonax traillii extimus*	Endangered BLM AZ BLM CA BLM NV	No habitat present for this species	Present	Habitat only in Lower Las Vegas Wash within full pool of Lake Mead	X
Western yellow-billed cuckoo	*Coccyzus americanus*	Threatened BLM AZ BLM CA BLM NV	No habitat present for this species	Habitat present in unaffected tributaries	Habitat only in Lower Las Vegas Wash within full pool of Lake Mead	Habitat in LCR MSCP conservatio n areas
Yuma Ridgway's rail	*Rallus obsoletus yumaniensis*	Endangered BLM AZ BLM CA BLM NV	No habitat present for this species	Habitat present above the waterline	Habitat in lower Grand Canyon within full pool of Lake Mead	Present
Mammals						
None						
Reptiles and Amphibians						
Desert tortoise	*Gopherus agassizii*	Threatened BLM NV	Not present	Not present	Present	Present
Northern Mexican garter snake	*Thamnophis eques megalops*	Threatened	Not present	Not present	Not present	Present
Invertebrates						
None						
Plants						
None						

Table 3-29
Non-ESA-listed Special Status Species potentially affected by the Alternatives

Common Name	Scientific Name	Status	Location			
			Lake Powell	Glen Canyon Dam to Lake Mead	Lake Mead	Hoover Dam to the SIB
Fish						
Bluehead sucker	*Catostomus discobolus*	BLM AZ BLM UT		X	X (rare)	X (rare)
Desert sucker	*Catostomus clarkii*	BLM AZ				X (found in tributaries)
Flannelmouth sucker	*Catostomus latipinnis*	BLM AZ BLM UT	X	X	X	X
Gila longfin dace	*Agosia chrysogaster chrysogaster*	BLM AZ				X (found in tributaries)
Sonora sucker	*Catostomus insignis*					X (found in tributaries)
Speckled dace	*Rhinichthys osculus*	BLM AZ	X (rare)	X	X	X
Virgin spinedace	*Lepidomeda mollispinis*				X (found in Virgin River upstream of project area)	
Woundfin	*Plagopterus argentissimus*				X (found in Virgin River upstream of project area)	
Birds						
American peregrine falcon	*Falco peregrinus*	BLM AZ BLM NV		X	X	X
American white pelican	*Pelicanus erythrorhynchos*	BLM UT	X			X[1]
Arizona bell's vireo	*Vireo bellii arizonae*	BLM CA				X
Arizona grasshopper sparrow	*Ammodramus savannarum ammolegus*	BLM AZ		X	X	X
Bald eagle	*Haliaeetus leucocephalus*	BLM AZ BLM NV BLM UT	X	X	X	X
Bank swallow	*Riparia riparia*	BLM CA				X
Bendire's thrasher	*Toxostoma bendirei*	BLM CA				X

Common Name	Scientific Name	Status	Location			
			Lake Powell	Glen Canyon Dam to Lake Mead	Lake Mead	Hoover Dam to the SIB
Black swift	*Cypseloides niger*	BLM UT	X			
Burrowing owl	*Athene cunicularia*	BLM AZ BLM UT BLM NV	X		X[1]	X
Cactus ferruginous pygmy owl	*Glaucidium brasilianum cactorum*	BLM AZ		X	X	X
California black rail	*Laterallus jamaicensis coturniculus*	BLM AZ BLM CA				X
California brown pelican	*Pelecanus occidentalis californicus*	BLM CA				X
California condor	*Gymnogyps californianus*	BLM AZ	X	X		
Crissal thrasher	*Toxostoma crissale*	BLM CA				X
Elf owl	*Micrathene whitneyi*	BLM CA				X
Ferruginous hawk	*Buteo regalis*	BLM UT	X			
Gila woodpecker	*Melanerpes uropygialis*	BLM CA				X
Gilded flicker	*Colaptes chrysoides*	BLM AZ BLM CA				X
Golden eagle	*Aquila chrysaetos*	BLM UT BLM AZ	X	X	X[1]	X
Least bittern	*Ixobrychus exilis*	BLM NV			X	X[1]
LeConte's thrasher	*Toxostoma lecontei*	BLM AZ		X	X	X
Lucy's warbler	*Vermivora luciae*	BLM CA				X
Mountain plover	*Charadrius montanus*	BLM CA				X
Northern goshawk	*Accipiter gentilis*	BLM AZ		X		
Phainopepla	*Phainopepla nitens*	BLM NV			X	X[1]
Swainson's hawk	*Buteo swainsoni*					X
Tricolored blackbird	*Agelaius tricolor*	BLM CA				X
Western snowy plover	*Charadrius nivosus nivosus*	BLM NV			X	
White-tailed kite	*Elanus leucurus*	BLM CA				X

Common Name	Scientific Name	Status	Location			
			Lake Powell	Glen Canyon Dam to Lake Mead	Lake Mead	Hoover Dam to the SIB
Mammals						
Allen's big-eared bat	*Idionycteris (=Plecotus) phyllotis*	BLM AZ BLM NV BLM UT	X		X	
Allen's lappet-browed bat	*Idionycteris phyllotis*	BLM AZ		X		
Arizona myotis	*Myotis occultus*	BLM AZ		X	X	X
Big brown bat	*Eptesicus fuscus*	BLM NV	X	X	X	X[1]
Big free-tailed bat	*Nyctinomops macrotis*	BLM NV			X	X[1]
California leaf-nosed bat	*Macrotus californicus*	BLM AZ BLM NV			X	X
California myotis	*Myotis californicus*	BLM NV	X	X	X	X[1]
Canyon bat	*Parastrellus hesperus*	BLM NV	X	X	X	X[1]
Cave myotis	*Myotis velifer*	BLM AZ BLM NV	X	X	X	X
Desert bighorn sheep	*Ovis canadensis nelsoni*	BLM CA	X	X	X	X
Fringed myotis	*Myotis thysanodes*	BLM UT BLM NV	X		X	
Hoary bat	*Lasiurus cinereus*	BLM NV			X	X[1]
Houserock Valley chisel-toothed kangaroo rat	*Dipodomys microps leucotis*	BLM AZ		X		
Kit fox	*Vulpes macrotis*	BLM UT	X			
Long-eared myotis	*Myotis evotis*	BLM CA				X
Mexican free-tailed bat	*Tadarida brasiliensis*	BLM NV	X	X	X	X[1]
Pale Townsend's big-eared bat	*Corynorhinus townsendii pallescens*	BLM AZ	X	X	X	X
Pallid bat	*Antrozous pallidus*	BLM NV	X	X	X	X
Palm springs pocket mouse	*Perognathus longimembris bangsi*	BLM CA				X
Palm springs round-tailed ground squirrel	*Xerospermophilus tereticaudus chlorus*	BLM CA				X

Common Name	Scientific Name	Status	Location			
			Lake Powell	Glen Canyon Dam to Lake Mead	Lake Mead	Hoover Dam to the SIB
Silver-haired bat	*Lasionycteris noctivagans*	BLM NV	X	X	X	X[1]
Spotted bat	*Euderma maculatum*	BLM AZ BLM NV BLM UT		X		X
Townsend's big-eared bat	*Corynorhinus townsendii*	BLM AZ BLM CA BLM NV BLM UT	X		X	X
Western mastiff bat	*Eumops perotis*	BLM AZ BLM NV		X	X	X
Western red bat	*Lasiurus blossevillii*	BLM NV BLM UT			X	X[1]
Western small-footed myotis	*Myotis ciliolabrum*	BLM CA BLM NV			X	X
Yuma myotis	*Myotis yumanensis*	BLM CA BLM NV	X	X	X	X
Reptiles and Amphibians						
Arizona striped whiptail	*Aspidoscelis arizonae*	BLM AZ		X	X	X
Arizona toad	*Anaxyrus microscaphus*	BLM AZ BLM UT BLM NV	X			X
Banded gila monster	*Heloderma suspectum cinctum*	BLM NV			X	X
Coast horned lizard	*Phrynosoma blainvillii*	BLM CA				X
Coronado skink	*Plestiodon skiltonianus interparietalis*	BLM CA				X
Couch's spadefoot	*Scaphiopus couchii*	BLM CA				X
Desert box turtle	*Terrapene ornata luteola*	BLM AZ		X	X	X
Flat-tailed horned lizard	*Phrynosoma mcallii*	BLM AZ				X
Foothill yellow-legged frog (south coast DPS)	*Rana boylii*	BLM CA				X

Common Name	Scientific Name	Status	Location			
			Lake Powell	Glen Canyon Dam to Lake Mead	Lake Mead	Hoover Dam to the SIB
Lowland burrowing treefrog	*Smilisca fodiens*	BLM AZ		X	X	X
Lowland leopard frog	*Rana yavapaiensis*	BLM AZ BLM CA			X	X
Mohave fringe-toed lizard	*Uma scoparia*	BLM AZ		X	X	X
Northern leopard frog	*Lithobates [=Rana] pipiens*	BLM AZ	X[2]	X		
Relict leopard frog	*Rana onca*	BLM AZ BLM NV			X	X
Sinoloan narrow-mouthed toad	*Gastrophryne mazatlanensis*	BLM AZ		X	X	X
Sonoran green toad	*Bufo retiformis*	BLM AZ		X	X	X
Two-striped garter snake	*Thamnophis hammondii*	BLM CA				X
Western pond turtle	*Emys marmorata*	BLM CA				X
Western spadefoot	*Spea hammondii*	BLM CA				X
Yuman desert fringe-toed lizard	*Uma rufopunctata*	BLM AZ		X	X	X
Invertebrates						
Apache springsnail	*Pyrgulopsis arizonae*	BLM AZ		X	X	X
Gila tyronia	*Tryonia gilae*	BLM AZ		X	X	X
Grand wash springsnail	*Pyrgulopsis bacchus*	BLM NV		X	X	X
Kingman springsnail	*Pyrgulopsis conica*	BLM AZ		X	X	X
MacNeill's sooty-winged skipper	*Hesperopsis gracielae*	BLM NV			X	X[1]
Mojave gypsum bee	*Andrena balsamorhizae*	BLM NV			X	
Mojave poppy bee	*Perdita meconis*	BLM NV			X	

Common Name	Scientific Name	Status	Location			
			Lake Powell	Glen Canyon Dam to Lake Mead	Lake Mead	Hoover Dam to the SIB
Monarch butterfly	*Danaus plexippus plexippus*	Candidate BLM NV		X	X	X
Sonoran talussnail	*Sonorella magdalenensis*	BLM AZ		X	X	X
Thorne's hairstreak	*Callophrys thornei*	BLM CA				X
Plants						
Alkali mariposa lily	*Calochortus striatus*	BLM NV			X	
Aravaipa sage	*Salvia amissa*	BLM AZ		X	X	X
Aravaipa woodfern	*Thelypteris puberula* var. *sonorensis*	BLM AZ		X		
Arizona eryngo	*Eryngium sparganophyllum*	BLM AZ		X	X	X
Arizona sonoran rosewood	*Vauquelinia californica ssp. sonorensis*	BLM AZ		X	X	X
Bartram stonecrop	*Graptopetalum bartramii*	BLM AZ		X	X	X
Beaver dam breadroot	*Pediomelum castoreum*	BLM NV			X	
Blue diamond cholla	*Cylindropuntia X multigeniculata*	BLM NV			X	
Blue sand lily	*Triteleiopsis palmeri*	BLM AZ		X	X	X
California flannelbush	*Fremontodendron californicum*	BLM AZ		X	X	X
California screw moss	*Tortula californica*	BLM CA				X
Chaparral sand-verbena	*Abronia villosa* var. *aurita*	BLM CA				X
Cochise sage	*Carex ultra*	BLM AZ		X	X	X
Coulter's goldfields	*Lasthenia glabrata ssp. coulteri*	BLM CA				X
Deane's milkvetch	*Astragalus deanei*	BLM CA				X
Decumbent goldenbush	*Isocoma menziesii* var. *decumbens*	BLM CA				X
Delicate clarkia	*Clarkia delicata*	BLM CA				X

Common Name	Scientific Name	Status	Location			
			Lake Powell	Glen Canyon Dam to Lake Mead	Lake Mead	Hoover Dam to the SIB
Dunn's mariposa lily	*Calochortus dunnii*					X
Fish creek fleabane	*Erigeron piscaticus*	BLM AZ		X	X	X
Felt-leaved monardella	*Monardella hypoleuca ssp. lanata*	BLM CA				X
Gander's pitcher sage	*Lepechinia ganderi*	BLM CA				X
Gander's ragwort	*Packera ganderi*	BLM CA				X
Gold butte moss	*Ceratodon purpureus*	BLM NV			X	
Grand Canyon rose	*Rosa stellata* var. *abyssa*	BLM AZ		X		
Harrison's barberry	*Berberis harrisoniana*	BLM AZ		X	X	X
Harwood's eriastrum	*Eriastrum harwoodii*	BLM CA				X
Hohokam agave	*Agave murpheyi*	BLM AZ		X	X	X
Horn's milkvetch	*Astragalus hornii* var. *hornii*	BLM CA				X
Huachuca golden aster	*Heterotheca rutteri*	BLM AZ		X	X	X
Lace-leaf rockdaisy	*Perityle ambrosiifolia*	BLM AZ		X	X	X
Lakeside ceanothus	*Ceanothus cyaneus*	BLM CA				X
Las Vegas bearpoppy	*Arctomecon californica*	BLM NV			X	
Las Vegas buckwheat	*Eriogonum corymbosum* var. *nilesii*	BLM NV			X	
Latimer's woodland-gilia	*Saltugilia latimeri*	BLM CA				X
Lincoln rockcress	*Boechera lincolnensis*	BLM CA				X
Little San Bernardino Mtns. linanthus	*Linanthus maculatus ssp. maculatus*	BLM CA				X

Common Name	Scientific Name	Status	Location			
			Lake Powell	Glen Canyon Dam to Lake Mead	Lake Mead	Hoover Dam to the SIB
Long-spined spineflower	*Chorizanthe polygonoides* var. *longispina*	BLM CA				X
Marble canyon milkvetch	*Astragalus cremnophylax* var. *hevronii*	BLM AZ		X		
Mecca-aster	*Xylorhiza cognata*	BLM CA				X
Mojave indigo bush	*Psorothamnus arborescens* var *pubescens*	BLM AZ		X		
Mojave tarplant	*Deinandra mohavensis*	BLM CA				X
Mokiak milkvetch	*Astragalus mokiacensis*	BLM NV			X	
Mt Trumbull beardtongue	*Penstemon distans*	BLM AZ		X		
Nuttall's scrub oak	Quercus dumosa	BLM CA				X
Oil neststraw	*Stylocline citroleum*	BLM CA				X
Orcutt's brodiaea	*Brodiaea orcuttii*	BLM CA				X
Orocopia Mountains spurge	*Euphorbia jaegeri*	BLM CA				X
Otay manzanita	*Arctostaphylos otayensis*	BLM CA				X
Otay Mountain ceanothus	*Ceanothus otayensis*	BLM CA				X
Parish's meadowfern	*Limnanthes alba ssp. parishi*	BLM CA				X
Parish's phacelia	*Phacelia parryi*	BLM NV			X	
Parry's spineflower	*Chorizanthe parryi* var. *parryi*	BLM CA				X
Parry's tetracoccus	*Tetracoccus dioicus*	BLM CA				X
Pima Indian mallow	*Abutilon parishii*	BLM AZ		X	X	X
Pinto beardtongue	*Penstemon bicolor ssp. roseus*	BLM AZ				X
Polished blazing star	*Mentzaelia laevicaulis*	BLM NV			X	

Common Name	Scientific Name	Status	Location			
			Lake Powell	Glen Canyon Dam to Lake Mead	Lake Mead	Hoover Dam to the SIB
Rainbow manzanita	*Arctostaphylos rainbowensis*	BLM CA				X
Ramona horkelia	*Horkelia truncata*	BLM CA				X
Reveal's buckwheat	*Eriogonum contiguum*	BLM CA				X
Robinson's monardella	*Monardella robisonii*	BLM CA				X
Rosy twotone beardtongue	*Penstemon bicolor ssp. roseus*	BLM NV			X	
Salt marsh bird's beak	*Chloropyron maritimum ssp. maritimum*	BLM CA				X
San Bernadino milkvetch	*San Bernardino milkvetch*	BLM CA				X
San Diego goldenstar	*Bloomeria clevelandii*	BLM CA				X
San Diego gumplant	*Grindelia hallii*	BLM CA				X
San Diego milkvetch	*Astragalus oocarpus*	BLM CA				X
Sandfood	*Pholisma sonorae*	BLM AZ		X	X	X
San Jacinto mariposa lily	*Calochortus palmeri* var. *munzii*	BLM CA				X
San Luis Obispo sedge	*Carex obispoensis*	BLM CA				X
San Miguel savory	*Clinopodium chandleri*	BLM CA				X
Sanford's arrowhead	*Sagittaria sanfordii*	BLM CA				X
Santa Lucia dwarf rush	*Juncus luciensis*	BLM CA				X
Scaly sandplant	*Pholisma arenarium*	BLM AZ		X	X	X
Shevock's copper moss	*Mielichhoferia shevockii*	BLM CA				X
Siler fishhook cactus	*Sclerocactus sileri*	BLM AZ		X		
Silverleaf sunray	*Enceliopsis argophylla*	BLM AZ BLM NV		X	X	X
Small wirelettuce	*Stephanomeria exigua ssp. exigua*	BLM AZ		X	X	X

Common Name	Scientific Name	Status	Location			
			Lake Powell	Glen Canyon Dam to Lake Mead	Lake Mead	Hoover Dam to the SIB
Snake cholla	*Cylindropuntia californica* var. *californica*	BLM CA				X
Spring mountains milkvetch	*Astragalus remotus*	BLM NV			X	
Sticky buckwheat	*Eriogonum viscidulum*	BLM AZ BLM NV			X	
Sticky dudleya	*Cylindropuntia californica* var. *californica*	BLM CA				X
Sticky ringstem	*Anulocaulis leiosolenus*	BLM NV			X	
Summer holly	*Comarostaphylis diversifolia ssp. diversifolia*	BLM CA				X
Tecate cypress	*Hesperocyparis forbesii*	BLM CA				X
Tecate tarplant	*Deinandra floribunda*	BLM CA				X
Threecorner milkvetch	*Astragalus geyeri* var. *triquetrus*	BLM NV			X	
Tumamoc globeberry	*Tumamoca macdougalii*	BLM AZ		X	X	X
Variegated dudleya	*Dudleya variegata*	BLM CA				X
White bearpoppy	*Arctomecon merriamii*	BLM NV			X	
White margined beardtongue	*Penstemon albomarginatus*	BLM NV			X	
White-bracted spineflower	*Chorizanthe xanti* var. *leucotheca*	BLM CA				X
Wiggins' croton	*Croton wigginsii*	BLM CA				X
Yellow twotone beardtongue	*Penstemon bicolor ssp. bicolor*	BLM NV			X	
Yucaipa onion	*Allium marvinii*	BLM CA				X

[1]Additional location information received from personal communication with Carolyn Ronning, Wildlife Group Manager, Reclamation, on March 3, 2023.
[2]Additional location information received from the NPS (2023l)

Colorado pikeminnow are stocked in the San Juan River annually as juveniles (Service 2022), and razorback sucker as large subadults. These fish are successfully reproducing in the San Juan River, but survival of young and recruitment of razorback sucker are low. Some fish are displaced from upstream populations into the Lake Powell inflow, and they are prevented from returning upstream by a 20-foot (6-meter) waterfall that has formed as the river has partly carved a new channel on the deltaic sediments. These species presently occupy about 30 miles of newly carved river each in the San Juan River and Colorado River inflows. Native fish in these inflows encounter large numbers of nonnative fish species that are potential predators and competitors, although the species and numbers of nonnative fish in the river channel are generally lower than in the body of the lake.

Glen Canyon Dam to Lake Mead

Table 3-28 lists all federally threatened, endangered, or proposed species and whether they occupy the Glen Canyon Dam to Lake Mead section. **Table 3-29** lists all non-ESA-listed special status species and whether they occupy the Glen Canyon Dam to Lake Mead section.

The flannelmouth sucker and bluehead sucker are "conservation species" that are included in a rangewide conservation agreement among six states (Utah Department of Natural Resources 2006). These species are found as self-sustaining populations and are common in the Colorado River from Glen Canyon Dam to Lake Mead. They are seasonally abundant during spring spawning runs into tributaries, such as Paria River, Havasu Creek, and Tapeats Creek. Both species have adjusted to changing riverine conditions following construction of Glen Canyon Dam (Paukert and Rogers 2004; Valdez and Carothers 1998). Speckled dace are locally common to abundant in and near tributary inflows, as well as on rocky debris fans formed by debris flows from side canyons (Valdez and Ryel 1995).

Humpback chub populations have recently expanded into the Western Grand Canyon over the last few years. This is likely due to the warmer water in the lower Grand Canyon and due to the lack of predators (Vanhaverbeke et al. 2017; Rogowski et al. 2018). The most recent information as of 2023 shows a population of 40,000-60,000 adults between Havasu Rapids and Pearce Ferry.[17]

Since 1944, only 10 razorback suckers have been reported from the Grand Canyon, including one from Bright Angel Creek, four from the mouth of the Paria River, one near Shinumo Creek, and four from the mouth of the Little Colorado River (Valdez et al. 2012). Since the year 2000, larvae and adult razorback suckers have also been found in the Colorado River inflow at the lower end of the Grand Canyon, including sonic-tagged adults moving from one of the three Lake Mead populations (Kegerries et al. 2017). A confirmed spawning site was located in 2010 about 10 miles downstream of Pearce Ferry (Valdez et al. 2012). The razorback sucker in the Grand Canyon is found only downstream of Lava Falls Rapid.

Lake Mead

Table 3-28 lists all federally threatened, endangered, or proposed species and whether they occupy Lake Mead. **Table 3-29** lists all non-ESA-listed special status species and whether they occupy Lake Mead.

Two native sucker species occupy this area and include flannelmouth sucker and razorback sucker (Reclamation 2007). The largest self-sustaining population of razorback sucker in the lower Basin is

[17] Personal communication with Randy Van Haverbeke, Service, Flagstaff, Arizona, March 2023.

found in Lake Mead. Humpback chub, bonytail, and Colorado pikeminnow do not occur in this reach.

Humpback chub have become established in the Colorado River extended channel as far downstream as Pearce Ferry (Rogowski et al., 2018), but they are not moving into Lake Mead and it is unlikely the species would move into the lake since it is primarily a riverine species. However, there is a large population of razorback sucker in Lake Mead, and the fish are reproducing in the upper reservoir near and in the inflows of both rivers (Albrecht et al. 2017). The newly hatched larvae use emergent vegetation that is inundated with spring runoff as shelter, although predation by nonnative fish is high and survival and recruitment are low (Service 2018a). In the Colorado River inflow, the razorback sucker is found in large numbers where it spawns on cobble shoals in April and May. The flannelmouth sucker is also found in the inflow, but at much lower numbers.

The endangered woundfin and the Virgin River roundtail chub are found in the Virgin River, but they do not occur downstream of Mesquite, Nevada, except when transported from upstream populations by large floods.

Hoover Dam to the SIB

Table 3-28 lists all federally threatened, endangered, or proposed species and whether they occupy the Hoover Dam to the SIB section. **Table 3-29** lists all non-ESA-listed special status species and whether they occupy the Hoover Dam to the SIB section.

The endangered razorback sucker and bonytail are introduced from hatchery stocks into Lake Mohave, Lake Havasu, and in the reach of river between Parker Dam and Imperial Dam as part of mitigation for the LCR MSCP. They are also stocked into lakeside rearing ponds in Lake Mohave and in created backwaters at Imperial NWR. There is some evidence of reproduction by these species, but self-sustaining populations have not become established.

The flannelmouth sucker and bluehead sucker are "conservation species" that are included in a rangewide conservation agreement among six states (Utah Department of Natural Resources 2006). The flannelmouth sucker is found in the riverine reach downstream of Hoover Dam. The bluehead sucker is found locally in tributary inflows.

3.13.2 Environmental Consequences

Methodology

Analyses in this section rely on the hydrologic modeling presented in **Sections 3.4** and **3.5** as well as models of vegetation impacts produced by Reclamation (2023l) and the USGS (Butterfield and Palmquist 2023a; 2023b). However, given the lack of comprehensive quantitative modeling results for vegetation impacts across the analysis area, the description of effects of this project on biological resources are largely qualitative.

These analyses also rely on hydrologic modeling for hourly releases from Glen Canyon Dam with the GTMax Model run by WAPA, and the smallmouth bass model developed by the USGS. As with vegetation analyses, fisheries impacts could not be quantitatively determined from relationships of flow to habitat or habitat to fish abundance, but rather as an evaluation of the hydrology associated with each alternative and as a professional scientific assessment.

Similar to the 2007 FEIS, this analysis evaluates the relative difference between the action alternatives and the No Action Alternative (Reclamation 2007). The level of available information varies with the study sections; therefore, the methodology is adjusted according to the availability of information for a particular section or group of sections. Impacts are only considered through December 2026.

Impact Analysis Area

The impact analysis area for vegetation and terrestrial wildlife is the same as the analysis area used for the 2007 FEIS, which includes the riparian vegetation and aquatic habitat from the northern tip of Lake Powell in Utah south to the SIB (**Map 1-1**; Reclamation 2007). The impact analysis area is divided into four sections: 1) Lake Powell, 2) Glen Canyon Dam to Lake Mead, 3) Lake Mead, and 4) Hoover Dam to the SIB. Note that the impact analysis area is not synonymous with the area where impacts could occur. The impact analysis area is a broader area intended to ensure all potential impacts are considered. The analysis below includes only species and impacts that would occur as a result of the alternatives analyzed. For example, many of the wildlife species listed as present in the impact analysis area would not actually be impacted by the project. See **Appendix E** for information narrowing the species in the impact analysis area to those potentially impacted by the alternatives.

The analysis area for fish and aquatic species includes the Colorado River and associated aquatic habitat that is contiguous with the mainstem Colorado River, including the interface with the riparian area, where applicable. The affected environment boundaries are demarcated from the northern tip of Lake Powell in Utah south to the SIB (**Map 1-1**).

Assumptions

Vegetation, Wildlife, and Special Status Species

The vegetation and wildlife and fish assumptions are the same as those described in the 2007 FEIS (Reclamation 2007). Desert scrub plant communities, and the wildlife that rely on these habitat types, would not be affected by operational changes at Glen Canyon and Hoover Dam, and are, therefore, not considered in this analysis. Davis Dam and Parker Dam would continue to operate to meet target reservoir elevations, and these operations would remain the same for all alternatives. The biological analysis is dependent upon the data inputs, modeling assumptions, and validity of the hydrology and riparian vegetation models. Impacts on fish species are based on hourly releases from Glen Canyon Dam using the GTMax Model runs by WAPA. DO and temperature of releases from Glen Canyon Dam are from modeling by the USGS, and information on smallmouth bass is from the smallmouth bass model developed by the USGS.

Impact Indicators

Vegetation

Impacts on vegetation within the analysis area are assessed based on changes in water elevation under the alternatives resulting in changes in vegetation, abundance, general location, and plant community composition. Impact indicators for vegetation remain the same as previously considered for the 2007 FEIS, including hydrologic modeling for the No Action Alternative (Reclamation 2007). Additionally, impacts on vegetation incorporate riparian and backwaters vegetation models provided by Reclamation and the USGS.

Wildlife

Similar to the 2007 FEIS, the analysis of impacts on terrestrial species is based on the vegetation impact analysis. Where impacts are noted for riparian vegetation, impacts are assumed for riparian terrestrial species. Impacts on fish incorporate findings from the 2007 FEIS where hydrological analysis was used to inform impacts. Additionally, impacts on the fish community incorporate model results from the GTMax Model and USGS Smallmouth Bass Model, where applicable.

Special Status Species

Similar to the 2007 FEIS, the analysis of impacts on terrestrial special status species are based on the vegetation impact analysis. Where impacts are noted for riparian vegetation, impacts are assumed for riparian special status species. Impacts on fish incorporate findings from the 2007 FEIS where hydrological analysis was used to inform impacts. Additionally, impacts on the fish community incorporate model results from the GTMax Model and USGS Smallmouth Bass Model, where applicable.

Issue 1: How would changing flow characteristics affect vegetation?

Summary

Under the No Action Alternative, with no modifications to water management to address worsening drought conditions, water elevations are projected to decrease over time in Lake Powell and Lake Mead to sustain flows in the Glen Canyon Dam to Lake Mead section and the Hoover Dam to the SIB section, resulting in short-term changes to riparian vegetation, including an increase of invasive plant species and loss of suitable habitat for native plant species. If HFEs were to be decreased or discounted under the No Action Alternative, there would be at least an order of magnitude greater adverse impact on vegetation resources than simply comparing Action Alternative 1 or 2 to the No Action Alternative with both scenarios having HFEs.

The types of impacts on riparian vegetation associated with each action alternative are similar, as the action alternatives only vary by magnitude and timing of effects. At Lake Powell and Lake Mead, fewer acres have the potential to be invaded by nonnative species under the action alternatives compared with the No Action Alternative. In most scenarios, impacts on riparian vegetation in the Glen Canyon Dam to Lake Mead section and the Hoover Dam to the SIB section would be greater under the action alternatives compared with the No Action Alternative, as water flows are reduced to these sections to maintain higher water elevations in Lake Powell and Lake Mead. These impacts include a short-term increase in suitable habitat for nonnative species and a decrease in native species of interest that have established in recent decades.

No Action Alternative

Lake Powell

Under the No Action Alternative, the 2007 FEIS and subsequent agreements would continue to guide operations in Lake Powell. With no modifications to water management to address worsening drought conditions, water releases are projected to decrease over time as water resources become depleted (**Figure 3-5**). **Figure 3-5** displays the median and resulting range of pool elevations that may occur in Lake Powell through 2026 based on CRMMS. In some of the driest potential hydrologic futures (**Section 3.6.2**, **Figure 3-5**), water elevations are projected to decline in the summer of 2023 through 2026. Therefore, it is expected that the trends discussed above in **Section 3.11.1** (i.e., encroachment of emergent wetland vegetation, increase in invasive species, etc.) would continue under this alternative.

The NPS is estimating that an additional 20,000 acres of shoreline would be exposed around Lake Powell under this No Action Alternative. It is anticipated that this additional acreage of exposed shoreline has the potential to be invaded by invasive plant species such as tamarisk and Russian thistle. An increase in tamarisk establishment would result in increased fire hazard, particularly during drought conditions. In addition, with lower reservoir elevations, cattle and wildlife may be forced to utilize springs and seeps rather than the reservoir for water, causing increased negative impacts such as trampling, spreading invasive species, and decreased water quality. Very little aquatic vegetation has established at Lake Powell, primarily because of the large (≥10 meters) year-to-year fluctuations in reservoir levels. Thus, aquatic beds of pondweed and shoreline wetlands of emergent vegetation are rare. These wetlands are important to plants and wildlife; by dropping reservoir levels even more, these wetlands may disappear completely (NPS 2023l).

Glen Canyon Dam to Lake Mead

Under the No Action Alternative, the 2007 Interim Guidelines and subsequent agreements would continue to guide operations at Glen Canyon Dam. Releases from Lake Powell under poor hydrologic conditions would deplete Lake Powell, exposing a large acreage of increased shoreline at Lake Powell. Releases from Lake Powell would remain the same as existing conditions, depleting Lake Powell but maintaining similar release levels from Glen Canyon Dam to Lake Mead. Therefore, it is expected that the current vegetation conditions, as described above and in the LTEMP EIS, would persist.

Hydrological niche modeling of 47 common riparian plant species growing on sand bars between Glen Canyon Dam and Diamond Creek at RM225 was conducted for the No Action Alternative (Butterfield and Palmquist 2023a). Separate analyses were conducted within three floristically distinct regions of the CR—Marble Canyon (RM0– RM61), eastern Grand Canyon (RM61–RM161), and western Grand Canyon (RM161–RM226)—and for native and nonnative plant species. The modeling results show projected net changes in suitable habitat for combined native and nonnative species across years (2023–2027) and ESPs (80 percent, 90 percent, 100 percent), along with projected losses and gains in suitable habitat for each species within each region. For the 100 percent ESP, projected trends for native and nonnative plant species for the period 2024–2027 under the No Action Alternative are as follows:

- Native species, as a group, are projected to lose suitable habitat in Marble Canyon (-3.4 percent), Eastern Grand Canyon (-0.8 percent), and Western Grand Canyon (-0.9 percent). Total change in habitat (either from suitable to unsuitable or vice versa) is projected to be 19.6 percent of the riparian area in Marble Canyon, 18.6 percent of Eastern Grand Canyon, and 22.8 percent of Western Grand Canyon. Other ESP scenarios have similar patterns.

- Nonnative species, as a group, are projected to gain suitable habitat in Marble Canyon (0.4 percent) and lose suitable habitat in Eastern Grand Canyon (-4.7 percent) and Western Grand Canyon (-6.6 percent). Total change in habitat (either from suitable to unsuitable or vice versa) is projected to be 24.8 percent of the riparian area in Marble Canyon, 16.8 percent of Eastern Grand Canyon, and 14.4 percent of Western Grand Canyon. Other ESP scenarios have similar patterns.
- Twelve native species exhibited overall increases in suitable habitat under these scenarios (No Action and 100 percent ESP) in Marble Canyon, while 17 exhibited losses. In Eastern Grand Canyon, 15 native species exhibited overall increases, while 15 exhibited losses. In Western Grand Canyon, 10 species exhibited increases, while 13 exhibited losses.
- Eight nonnative species exhibited overall decreases in suitable habitat under these scenarios (No Action and 100 percent ESP) in Marble Canyon, while 4 exhibited increases. In Eastern Grand Canyon, 10 nonnative species exhibited overall losses, while 4 exhibited gains, with weeping lovegrass (*Eragrostis curvula*) exhibiting a large increase. In Western Grand Canyon, 7 nonnative species exhibited losses, while 2 exhibited modest or minor gains (Butterfield and Palmquist 2023a).

With continued drought conditions, as water elevations continue to decline in Lake Powell and the lake drops below minimum power pool elevation and approaches dead pool, less water would be available for release in this reach and HFEs would be decreased or discontinued. At this point, riparian habitat may be further impacted. To demonstrate this, an additional set of comparisons was conducted (Butterfield and Palmquist 2023b), in which Action Alternative 1 with HFEs was compared with the No Action Alternative without HFEs, focusing on the 80 percent ESP and subdividing by traces from worst- to best-case scenarios with respect to lake levels. The results of this comparative modeling are described below under Action Alternative 1.

Lake Mead

Under the No Action Alternative, the 2007 Interim Guidelines and subsequent agreements would continue to guide operations in Lake Mead. With no modifications to water management to address worsening drought conditions, water elevations are projected to decrease over time as water resources become depleted (**Figure 3-8**). Water elevations are projected to decline in the summer of 2023 and continue through 2026. Therefore, it is expected that the trends discussed above in **Section 3.11.1** (i.e., encroachment of emergent wetland vegetation, increase in invasive species, etc.) would continue under this alternative.

Hoover Dam to the SIB

Under the No Action Alternative, the 2007 Interim Guidelines and subsequent agreements would continue to guide operations at Hoover Dam. Releases from Lake Mead would remain the same as existing conditions, depleting Lake Mead but maintaining similar water elevations from Lake Mead to SIB. Therefore, it is expected that the current vegetation conditions, as described above in **Section 3.11.1** and in the LCR MSCP HCP, would persist. However, with continued drought conditions, as water elevations continue to decline in Lake Powell and the lake drops below minimum power pool elevation and approaches dead pool, less water would be available for release in this reach (**Table 3-30**), at which point riparian habitat may be impacted.

Action Alternative 1

Lake Powell

Implementation of Alternative 1 would result in an increasing trend in Lake Powell's elevation (**Figure 3-5**). By 2026, the median elevation is projected to be 3,550 feet (1,082 meters), which is within the Mid-Elevation Release tier. Overall, more water would be preserved in Lake Powell and variability in water surface elevation would be reduced. Initial impacts on vegetation from implementation of this alternative would include inundation of vegetation that has established along the shoreline in response to lower water levels and an overall decrease in riparian plant habitat. However, as the elevation of the lake stabilizes, an upward shift in the riparian zone would occur. The NPS projected that a maximum of 8,000 acres have the potential to be invaded by nonnative plant species, which is substantially less than the number of possible infested acres under the No Action Alternative (NPS 2023l).

Glen Canyon Dam to Lake Mead

Hydrological niche modeling for the Action Alternative 1 scenario as it relates to the No Action Alternative show projected net changes in suitable habitat for combined native and nonnative species across years (2023–2027) and ESPs (80 percent, 90 percent, 100 percent), along with projected losses and gains in suitable habitat for each species within each region. In general, the riparian vegetation model did not project substantial changes in habitat suitability under Action Alternative 1 compared with the No Action Alternative, with one exception. Action Alternative 1 would result in statistically significantly less projected habitat for native species under the 80 percent ESP scenario (**Table 3-30**). Variation in projected net habitat change accumulated across all riparian plant species was greater among traces than between ESPs. However, there were some notable differences between ESPs, which are described below by region. Furthermore, these net habitat changes obscure substantial variation among species in projected habitat gains and losses (Butterfield and Palmquist 2023a).

Table 3-30
Overall Summary of Riparian Plant Community Modeling Comparing the Projected Suitable Habitat under Action Alternative 1 as Compared with the No Action Alternative

River Segment	ESP	Action Alternative 1 Relative to No Action Alternative					
		Native Species	Native Species with Gains	Native Species with Losses	Nonnative Species	Nonnative Species with Gains	Nonnative Species with Losses
Marble Canyon	100%	Similar	twin bugs, common reed	Jointed rush, alkali muhly, Emory's baccharis	Similar	annual grasses, salt cedar	horseweed, some perennial grasses
	90%	Similar			Greater		
	80%	Similar			Greater		
Eastern Grand Canyon	100%	Similar	twin bugs, common reed	Emory's baccharis, mule fat, cane bluestem	Similar	annual grasses, salt cedar	horseweed, some perennial grasses
	90%	Greater			Similar		
	80%	Greater			Similar		

River Segment	ESP	Action Alternative 1 Relative to No Action Alternative					
		Native Species	Native Species with Gains	Native Species with Losses	Nonnative Species	Nonnative Species with Gains	Nonnative Species with Losses
Western Grand Canyon	100%	Similar	twin bugs, catclaw acacia, dropseed grasses, arrowweed	Emory's baccharis, mule fat, cane bluestem, alkali goldenbush	Similar	annual grasses, salt cedar	beard grass
	90%	Similar			Similar		
	80%	Declining over time			Similar		

Source: Butterfield and Palmquist 2023a.
Note: Similar – projected suitable habitat is similar to No Action Alternative; Greater – projected suitable habitat is greater than for No Action Alternative; Declining over time – projected suitable habitat declines to less than the No Action Alternative over the 5-year span.

In Marble Canyon, nonnative species show sustained increases in suitable habitat for the majority of traces under the 80 percent and 90 percent ESPs compared with the 100 percent ESP, while native species did not. The **nonnative species** with greatest projected gains in suitable habitat included annual grasses (*Bromus* species and *Schismum arabicus*) and salt cedar (*Tamarix*), while horseweed (*Conyza canadensis*) and several perennial grass species (*Polypogon viridis*, *Eragrostis curvula* and *Schedonorous arundinaceus*) had the greatest projected losses. **Native species** with greatest projected habitat gains were the annual forb twin bugs (*Dicoria canescens*) and common reed (*Phragmites australis*), while those with the greatest projected losses included jointed rush (*Juncus articulatus*), bunchgrass alkali muhly (*Muhlenbergia asperifolia*), and the large shrub Emory's baccharis (*Baccharis emoryi*) (Butterfield and Palmquist 2023a).

In eastern Grand Canyon, native and nonnative species exhibited the opposite pattern from Marble Canyon with respect to net projected habitat change, with native species showing sustained increases in suitable habitat under the 80 percent and 90 percent ESPs, and nonnative species showing no difference from the 100 percent ESP. The **nonnative species** with greatest projected gains and losses were the same as in Marble Canyon. The **native species** with greatest projected gains were the same as in Marble Canyon, specifically twin bugs and common reed. Once again, Emory's baccharis had high projected losses, as did mule fat (*Baccharis salicifolia*) and the perennial grass cane bluestem (*Bothriochloa barbinodis*) (Butterfield and Palmquist 2023a).

In western Grand Canyon, projected net habitat change became increasingly negative over time for native species under the 80 percent ESP, but did not differ from the 100 percent ESP scenario in all other cases. The **nonnative species** with greatest projected gains were the same as in the other regions, while beard grass (*Polypogon viridis*) was the only species with significant losses relative to gains. The **native species** with greatest projected gains were twin bugs, catclaw acacia (*Acacia greggii*), several species of dropseed grasses (*Sporobolus* species), and arrowweed (*Pluchea sericea*). Those with the greatest projected losses were the same as in eastern Grand Canyon, with the addition of alkali goldenbush (*Isocoma acradenia*) (Butterfield and Palmquist 2023a).

In summary, total vegetation can be expected to increase in Marble Canyon and eastern Grand Canyon, driven by nonnative and native species, respectively, and to decline in western Grand Canyon, driven by native species. However, these general trends are weak relative to the variation among traces, and obscure substantial shifts in suitable and unsuitable habitat among species as water levels decline. This variability also reflects the individualistic responses of different species to various aspects of hydrology and climate, revealed by the species-specific changes in habitat suitability shown here. In general, suitable habitat is expected to increase across all three regions for nonnative, fire-prone annual grasses and salt cedar. Likewise, the native common reed is expected to increase in suitable habitat in Marble Canyon and eastern Grand Canyon, though possibly decline in western Grand, while native dropseed, catclaw acacia, and arrowweed are expected to increase in western Grand Canyon. Water-loving baccharis species are expected to decrease in suitable habitat across all three regions.

When Action Alternative 1 with HFEs is contrasted with the No Action Alternative without HFEs, focusing on the 80 percent ESP (Butterfield and Palmquist 2023b), projections averaged across the 2024–2027 period, among the lowest water 10th percentile of traces, are as follows:

- Overall, projected effects of losing HFEs under the No Action Alternative have at least an order of magnitude greater impact on vegetation resources than simply comparing Action Alternative 1 with the No Action Alternative, with both scenarios having HFEs (as described above).
- Total vegetation is expected to be reduced by 33.7 percent under Action Alternative 1 with HFEs; however, it affects groups differentially. Native vegetation is expected to be reduced by 41 percent and nonnative vegetation is expected to increase by 20.1 percent.
- Native species of interest that have expanded in recent decades are expected to be reduced under Action Alternative 1 with HFEs (i.e., desert broom, coyote willow, arrowweed, and common reed) with the most dramatic decrease in water-loving species that have expanded near the river channel.
- Nonnative species of interest are projected to exhibit more variable responses:
    - Fire-prone annual grasses in the genera *Bromus* and *Schismus* are expected to increase substantially.
    - *Tamarix* is expected to increase slightly, while *Schedonorous arundinaceus* is expected to decrease substantially (Butterfield and Palmquist 2023b).

Lake Mead

Implementation of Action Alternative 1 would cause an initial decrease in the elevation of Lake Mead followed by a steady increase starting in mid-2024. By the end of 2026, the median elevation is projected to be 1,015 feet (309 meters), which is still within shortage conditions. Overall, more water would be preserved in Lake Mead under this alternative compared with the No Action Alternative, and impacts on vegetation would be similar to those described for Lake Powell. However, these impacts would be less pronounced at Lake Mead due to differences in geomorphology and because the projected difference in the lake elevation compared with the No Action Alternative is smaller than that at Lake Powell.

Hoover Dam to the SIB

In general, impacts on vegetation within this stretch from implementation of Action Alternative 1 would be similar to the impacts described for the Glen Canyon Dam to Lake Mead section of river.

In addition, Reclamation modeling using Reclamation's 2000 backwater mapping was conducted to determine potential changes in marshes/backwater emergent vegetation under this alternative using the methodology described in Appendixes J and K of the LCR MSCP HCP. The model showed that with an increase in flow reduction from Hoover Dam, there would be a corresponding short-term increase in impacts on backwater emergent wetland vegetation and open-water areas of backwaters. Reduced flows under this alternative may also result in less water available for implementation of conservation actions associated with the LCR MSCP HCP, described above in **Section 3.13.1**.

Action Alternative 2

Action Alternative 2 modifies water delivery priorities compared with Action Alternative 1, which would not have a measurable impact on vegetation. Therefore, impacts on vegetation would be similar to those described under Action Alternative 1 for all analysis areas.

Cumulative Effects

If one of the Glen Canyon Dam Smallmouth Bass flow options were implemented, it would not have a measurable effect on vegetation. Generally, all other actions that could result in cumulative impacts on vegetation have been incorporated into the modeling of future system conditions and described under the affected environment in **Section 3.11.1**. Therefore, no cumulative effects on vegetation are anticipated.

Issue 2: How would changing flow characteristics affect wildlife?

Riparian habitat is common along the banks of the Colorado River and the vegetation community in this area is most affected by changes in flow characteristics. Many wildlife species that utilize the analysis area are habitat generalists that use a combination of upland and riparian habitat (Reclamation and NPS 2016). These species are less susceptible to changes in riparian habitat availability. However, some species are obligate riparian species, relying on riparian habitat for all stages of their life cycle. These species can be sensitive to changes in habitat availability (Reclamation and NPS 2016). Species that utilize riparian habitat are discussed further below.

Numerous upland wildlife species are found within the analysis area that do not rely on riparian vegetation. Consistent with the analysis in the 2007 FEIS, no impacts of these alternatives are expected to these species (Reclamation 2007). Therefore, these species are not discussed further in this analysis.

Flow is an important factor in managing native and nonnative fish, and responses to reduced flows and declining lake elevations may impact fish species on a species-specific basis as well as based on developmental phase or life history. Furthermore, levels of discharge and lake elevations may also affect water temperatures, which can affect habitat availability and utilization on a species-specific and developmental-phase level. For example, reduction in flows can potentially reduce available lacustrine habitat while increasing riverine habitat as lake levels drop and more river channel is exposed at the inflow. Impacts on reduced flows and habitat availability were evaluated on a reach-specific basis.

Summary

The type of impacts associated with each alternative are similar, as alternatives vary only by magnitude and timing of effects. The No Action Alternative would result in increased impacts on terrestrial wildlife at Lake Powell and Lake Mead compared with Action Alternative 1 and Action Alternative 2. With no modifications to water management to address worsening drought conditions, water elevations are projected to decrease over time as water resources become depleted in Lake Powell and Lake Mead to sustain flows in the Colorado River below Glen Canyon Dam to Lake Mead and the Hoover Dam to the SIB sections. The retention of water in Lake Powell under Action Alternatives 1 and 2 provides for the opportunity for high-flow experimental releases that may mitigate some impacts in the Glen Canyon Dam to Lake Mead section related to beach building and sediment transport. This would make Action Alternatives 1 and 2 preferable to the No Action Alternative for terrestrial wildlife.

In most potential hydrologic futures (**Section 3.6.2**), impacts on terrestrial wildlife in the Colorado River below the Hoover Dam to the SIB section would be greater under Action Alternative 1 and Action Alternative 2 compared with the No Action Alternative, as water flows are reduced to these sections to maintain higher water elevations in Lake Powell and Lake Mead.

However, in some potential hydrologic futures (**Section 3.6.2**, **Figure 3-8**), Lake Mead would hit dead pool in early 2026. Under the No Action Alternative, no contingencies are in place to prevent Lake Mead from reaching dead pool. This would result in catastrophic impacts on the Hoover Dam to SIB section, as no water could be released beyond the inflows (run of the river operations). Action Alternative 1 and Action Alternative 2 have contingencies in place to reduce flows should Lake Mead be at risk of reaching dead pool to ensure flowing water in all sections (**Chapter 2**).

No Action Alternative

Lake Powell

In some of the driest potential hydrologic futures (**Section 3.6.2**, **Figure 3-5**), water elevations are projected to decline in summer 2023 and continue to decline through 2026.

Reduced water elevation would alter riparian vegetation, with increased invasive vegetation colonizing newly exposed sediments (see vegetation section) impacting terrestrial wildlife species that utilize riparian habitat. In this portion of the analysis area, riparian habitat is a limited resource. Given the limited amount of riparian habitat available around Lake Powell, most species that utilize riparian habitat in this area are likely habitat generalists that have adapted to changing riparian habitat availability over the preceding years (Reclamation 2007). Therefore, impacts on terrestrial wildlife would be similar to those described in the 2007 FEIS (Reclamation 2007), with an increasing magnitude of effects as water elevations decrease.

If conditions continue to degrade in the form of reduced water availability, declining lake levels, and reduced available flows for release, there are likely multiple results from this scenario for aquatic species. The low lake levels have resulted in exposed deltaic deposits, through which both the Colorado River and San Juan River have carved new channels. Further declining lake levels would likely expand or increase riverine habitat benefiting riverine species in the inflows to Lake Powell as riverine habitat is increased in the San Juan River and other Colorado River inflows. There are various nonnative fish species in Lake Powell, and some were introduced as sport fish or forage fish. The No Action Alternative may lead to changing habitats conditions for nonnative fish such as smallmouth bass, channel catfish, and other centrarchids through lower lake levels and warmer water temperatures. Depending on lake levels, decreasing talus shoreline spawning habitat of largemouth bass, smallmouth bass, bluegill, and other centrarchids. can be negatively affected, resulting in long-term population changes in these species. Additionally, reduced lake levels may reduce the amount of available habitat for midwater forage fish such as threadfin shad that are used to support the nonnative sport fishery in the lake. Low reservoir elevations may also negatively affect reservoir productivity and available food supplies for these nonnative fish.

Glen Canyon Dam to Lake Mead

If water elevations continue to decline in Lake Powell, less water will be available for release below Glen Canyon Dam to Lake Mead by 2026. Riparian vegetation along this stretch would be impacted as water levels dropped. Some vegetation in the current riparian zone would be expected to die off while new vegetation colonized the lower riparian zone. The timing of this transition is unknown but may begin within the analysis window of 2026 and continue afterward. During this transitional period, there could be impacts on species that utilize riparian habitat (Butterfield and Palmquist 2023; Holm et al. 2023).

Lower water levels could impact invertebrate biodiversity and have subsequent effects on species that rely on invertebrates for food. Specifically, bat species could be impacted by changing prey availability causing reduced fitness and increased susceptibility to white-nose syndrome (Holm et al. 2023).

There are about 18 species of nonnative fish (Valdez and Carothers 1998) that have been detected in the Colorado River below Glen Canyon Dam through the Grand Canyon; however, most of them are not established as self-sustaining populations, and the fish community is predominantly composed of native species. The lowered lake elevation and reduction in releases from Glen Canyon Dam under the No Action Alternative could result in increased water temperatures that could benefit nonnative fish species such as smallmouth bass, common carp, channel catfish, bullheads, green sunfish, fathead minnows, and red shiners. This may result in increased interactions between nonnative and native fish and result in potential predation and competition on native fish.

Species such as rainbow trout and brown trout prefer colder water, and the warmer water temperatures would provide less suitable conditions for both trout species. With increased temperatures (above 18°C), parasites such as Asian tapeworm (*Bothriocephalus acheilognathi*) and anchorworms (*Lernaea cyprinacea*) could be expected to increase. The Asian tapeworm can block the intestine of fish and lead to death, and anchorworm can cause infections on attachment points on the body and fins. A reduction in releases from Glen Canyon Dam may also increase the river's water clarity and the possibility of predation by sight predators, such as rainbow trout and brown trout, on native fish (Ward et al. 2016). This effect of reduced turbidity could be offset by warmer temperatures that will reduce the swimming efficiency of trout and improve the efficiency of warmwater species, such as humpback chub, razorback sucker, and flannelmouth sucker (Valdez and Carothers 1998).

Sandbars that form as reattachment bars associated with large, recirculating eddies form recurrent channels that are backwaters used by native fish in the Colorado River through the Grand Canyon. At certain flow ranges, these backwaters are used extensively by young humpback chub and flannelmouth suckers. These backwaters provide warm sheltered habitats for these fish and are important habitats for improved survival and recruitment of native fish (Dodrill et al. 2014). These backwaters may be impacted by different releases from Glen Canyon Dam, as low releases may desiccate these habitats and high releases may inundate them.

According to the USGS Smallmouth Bass Model (Yackulic 2023), smallmouth bass entrainment through Glen Canyon Dam may increase under the No Action Alternative compared with Action Alternative 1 and Action Alternative 2. However, entrainment depends on specific hydrologic traces, and hydrologic traces where low inflows occur may increase entrainment even under the action alternatives. In dry hydrologic traces, both alternatives would have increased entrainment compared with the No Action Alternative. Population growth is expected to be the same between the No Action Alternative and Action Alternative 1 in wet years.

Overall, both action alternatives are likely to result in less population growth than the No Action Alternative. However, in the driest hydrologic traces, both action alternatives result in substantial population growth. In the 25 percent of driest traces, Action Alternative 1 may result in increases in population growth of approximately 500 percent over the 4-year period of analysis. As indicated, entrainment and population growth of the smallmouth bass population will largely depend on whether the hydrologic scenario resembles a dry, moderate, or wet hydrological trace. This model indicated that population growth depended on the degree of available water during the modeled period.

Under the No Action Alternative, the GTMax Model shows that releases through the penstocks at Glen Canyon Dam would drop to zero from January through April 2024, meaning that water would be released through the river outlets where power is not generated. At low levels of Lake Powell, release temperatures are projected to be as high as 20°C, and switching to releasing water through the river outlets would mean much colder release temperatures of 10-12° C. This cold-release regime would be similar to releases prior to 2004 when the reservoir was above 3,600 feet elevation (Valdez et al. 2015). There could be an effect, however, on fish populations downstream of Glen Canyon Dam when the temperature of the water released shifts from warm water to cold water. This colder release could shock juvenile and adult rainbow trout in the Lees Ferry reach as well as eggs and fry that would be in the gravel beds at that time.

Lake Mead

Given the limited amount of riparian habitat available around Lake Mead, most species that utilize riparian habitat in this area are likely habitat generalists that have adapted to changing riparian habitat availability over the preceding years (Reclamation 2007). Therefore, impacts on terrestrial wildlife would be similar to those described in the 2007 FEIS (Reclamation 2007), with an increasing magnitude of effects as water elevations decrease. In areas where new sediments are exposed, larger animals may become stuck in deep mud and die. This is currently occurring and may be exacerbated with declining lake levels under this alternative.

The No Action Alternative may likely improve and increase habitat for nonnative fish that prey upon native species. Additionally, reduced lake levels may reduce the amount of available habitat for forage fish that are used to support the nonnative fishery for sportfish in the lake. Like Lake Powell, Lake Mead has a large variety of nonnative fish species that are valuable as sport fish and as forage fish. Reductions in lake levels would not have as extensive an effect on shoreline spawners as in Lake Powell because the shoreline of Lake Mead is gentle and sloping with cobble shoals that extend at a variety of lake levels.

Both Lake Mead and Lake Mohave have experienced algal blooms since the early 2000s. These blooms are the result of nutrients within the Colorado River generally derived from decaying vegetation in the largely undeveloped watershed, as well as nutrients from the Virgin River, Muddy River and Las Vegas Wash. These nutrients arrive in the form of treated wastewater, urban runoff, and agricultural runoff. Lower lake levels affect lake nutrients as well as nutrient dynamics. These in turn affect the amounts and location of algae produced in these reservoirs. Starting in the year 2000, the wastewater treatment plants along Las Vegas Wash have enhanced their phosphorus removal improving water quality and reducing the potential for algal blooms. Monitoring has revealed that these blooms include blue-green algae, which bloomed in large amounts in 2011–2015, and again in recent years since 2020. Blue-green algae produces a toxin called microcystin that can cause health issues with people and wildlife. The effects of these algal blooms on fish and wildlife are not well understood, and monitoring will need to be continued to better understand the relationship between reservoir elevations, algal blooms, and effects on fish populations in both Lakes Mead and Mohave.

Hoover Dam to the SIB

Given the decrease in water elevations projected in Lake Mead, less water would be available for release into this section.

Overall, reductions in water availability would have the same impacts on native fish through reduction of habitat such as backwater and floodplains. Reduced flows and increased water temperatures may also improve suitable habitat for nonnative fish such as flathead catfish and channel catfish; thereby, also increasing potential for predation on native species.

In some of the driest potential hydrologic futures (**Section 3.6.2**, **Figure 3-8**), Lake Mead hits dead pool in early 2026. At this point, no water would be released from Lake Mead into the Hoover Dam to SIB section, severely limiting water resources in this section. Water in this section would be limited to inflows that enter the Colorado River below Hoover Dam. It is likely that these inflows would be insufficient to support aquatic species populations, leading to extirpation or extreme reductions in population numbers. Wildlife capable of moving to alternative habitat areas may be able to locate resources outside of the Colorado River corridor. Species that are not able to move to alternative habitat areas may become extirpated from the area.

Action Alternative 1

Lake Powell

No additional impacts beyond those described in the 2007 FEIS (Reclamation 2007) are expected on terrestrial wildlife species under this alternative.

Overall, Action Alternative 1 maintains higher water levels in Lake Powell throughout the entire period compared with the No Action Alternative. This would likely result in no negative impacts on the nonnative sport fish in the lake. Maintaining higher lake elevations also would not negatively affect native riverine species; however, it may reduce the length of riverine habitat associated with the inflow into Lake Powell compared with scenarios where lake elevation is reduced.

Glen Canyon Dam to Lake Mead

After implementing Action Alternative 1, releases from Lake Powell would be reduced, which would result in lower river flows in this section compared with the No Action Alternative.

The riparian vegetation model projects similar or greater native plant species availability under Action Alternative 1 compared with the No Action Alternative in all modeled areas except for in the western Grand Canyon area. In this area, native plant species availability would be lower under Action Alternative 1 compared with the No Action Alternative under the 80 percent ESP, which evaluates a worse-case scenario. Nonnative plant species availability is projected to be similar or greater under Action Alternative 1 compared with the No Action Alternative. Nonnative plant species provide lower-quality habitat than native species and can lead to monotypic habitat types that support fewer wildlife species (NatureServe 2023).

Impacts on terrestrial wildlife would be similar to those described in the 2007 FEIS (Reclamation 2007), with an increasing magnitude of effects as water elevations begin to decrease and nonnative plant cover increases. However, the greater likelihood for high-flow experimental releases under this alternative, relative to the No Action Alternative, reduces some of the impacts described under that alternative. Specifically, the likelihood of impacts on invertebrate diversity and subsequent prey availability effects would be reduced (Holm et al. 2023).

Action Alternative 1 would maintain flows of 5,000 cfs during the night and 8,000 cfs during the day within the LTEMP operations. This flow scenario would maintain shoreline habitat conditions for juvenile humpback chub and large recirculating eddies for adults. Compared with the No Action Alternative, Action Alternative 1 would maintain more suitable habitat conditions for humpback chub through the Grand Canyon. Action Alternative 1 would also provide suitable habitat conditions for razorback sucker that are present downstream of Lava Falls Rapid.

According to the USGS Smallmouth Bass Model (Yackulic 2023), Action Alternative 1 is likely to decrease the risk of entrainment (fish passage) of smallmouth bass compared with the No Action Alternative. However, entrainment depends on specific hydrologic traces, and hydrologic traces where low inflows occur may increase entrainment even under the action alternatives. In dry hydrologic traces, Action Alternative 1 would have increased entrainment compared with the No Action Alternative. Population growth is expected to be the same between the No Action Alternative and Action Alternative 1 in wet years.

Overall, Action Alternative 1 is likely to result in less population growth than the No Action Alternative. However, in the driest hydrologic traces, Action Alternative 1 is likely to result in substantial population growth. In the 25 percent of driest traces, Action Alternative 1 may result in increases in population growth of approximately 500 percent over the 4-year period of analysis. As indicated, entrainment and population growth of the smallmouth bass population will largely depend on whether the hydrologic scenario resembles a dry, moderate, or wet hydrological trace.

Lake Mead

Given the limited amount of riparian habitat available around Lake Mead, most species that utilize riparian habitat in this area are likely habitat generalists that have adapted to changing riparian habitat availability over the preceding years (Reclamation 2007). Therefore, impacts on terrestrial wildlife would be similar to those described in the 2007 FEIS (Reclamation 2007), with an increasing magnitude of effects as water elevations decrease. Impacts associated with wildlife becoming trapped in soft sediments would be more likely under this alternative, as more sediments would be exposed.

Reduction of lake elevation is expected to occur at a greater rate than the No Action Alternative under the 80 percent ESP until approximately August 2025. This would likely improve and increase habitat for nonnative fish. Additionally, reduced lake levels may reduce the amount of available habitat for forage fish that are used to support the nonnative fishery for sportfish in the lake. Following August 2025, this reduction would lessen and result in increased lake elevations compared with the No Action Alternative.

Action Alternative 1 would help to stabilize the elevation of Lake Mead and therefore continue to provide extended riverine habitat for the humpback chub. This area would also provide suitable habitat for the razorback sucker.

Hoover Dam to the SIB

After implementing Action Alternative 1, releases from Lake Mead would be reduced, which would result in lower water elevations in this section compared with the No Action Alternative. Impacts on riparian vegetation and terrestrial wildlife species would, therefore, be greater under Action Alternative 1 than the No Action Alternative in all but the driest potential hydrologic futures (**Section 3.6.2**, **Figure 3-8**).

However, in the driest potential hydrologic futures (**Section 3.6.2**, **Figure 3-8**), where Lake Mead is projected to reach dead pool, water deliveries from Lake Mead would be reduced in advance to avoid reaching these levels. Should these adjustments prove successful, the scenario of no water passing through Hoover Dam would not occur. Water levels in the section between Hoover Dam and the SIB could be critically low, but there would still be flow in the river to support aquatic species at levels substantially greater than those described under the No Action Alternative.

The fish community is dominated by nonnative fish, and the continued drop in water would likely result in improved habitat for nonnative species, continued pressure on native species, and potentially more interactions between nonnative and native species. Backwater habitats that presently occur in this reach and support stocked populations of razorback sucker and bonytail will be better sustained under Action Alternative 1 than under the No Action Alternative.

Action Alternative 2

Action Alternative 2 modifies water delivery priorities compared with Action Alternative 1 and marginally increases the water supply to Lake Powell through releases of water from the Upper Basin reservoirs. This would result in marginally more water available throughout the system compared with Action Alternative 1. These marginal increases in water could be meaningful in the driest potential hydrologic futures (**Section 3.6.2**), especially immediately downstream of Hoover Dam. Also, the changes in water allocations under this alternative, relative to Action Alternative 1, would result in more water in the Colorado River between Hoover Dam and the locations where water is diverted for uses in California. However, these differences are minimal when considering impacts on wildlife. Therefore, overall impacts on wildlife species are similar to those described under Action Alternative 1 for all analysis sections other than part of the Hoover Dam to SIB section, where impacts of Action Alternative 2 are reduced compared with Action Alternative 1.

Cumulative Effects

The Glen Canyon Dam Smallmouth Bass flow options described in the environmental assessment that Reclamation is pursuing is the only cumulative action identified in **Section 3.5.1**. If one of the flow options were implemented, this action would cumulatively impact aquatic species within the Colorado River below Glen Canyon Dam to Lake Mead due to a reduction in the temperature of water released. The intent of this action is to prevent the establishment of invasive smallmouth bass. Prevention of smallmouth bass establishment is important because smallmouth bass are adept predators with wide diet variability and may impact native fish (Bestgen and Hill 2016). Under all alternatives analyzed in this SEIS, the effects of this cumulative action would be beneficial for aquatic wildlife species unless water levels in Lake Powell reached minimum power pool levels. At minimum power pool, water would be released through the river outlet works out of necessity, nullifying this cumulative action.

Under the driest hydrologic futures, both alternatives are expected to increase smallmouth bass population growth substantially. For example, in the driest 25 percent of hydrologic traces, Action Alternative 1 increases smallmouth bass population growth by an average of approximately 500 percent over the 4-year period as compared with the No Action Alternative. Under moderate hydrologic scenarios, both alternatives would decrease smallmouth bass population growth. Under the wettest hydrologic traces, all alternatives would perform similarly (Yackulic 2023).

Issue 3: How would changing flow characteristics affect special status species?

Numerous upland special status species are found within the analysis area that do not rely on riparian vegetation nor grow in riparian habitat. Consistent with the finding of the 2007 FEIS analysis, no impacts of the alternatives analyzed in this SEIS are expected on these species (Reclamation 2007). A complete list of all special status species from **Table 3-31** and **Table 3-32** not analyzed in detail, and their habitat needs, is included in **Appendix E**, Table of Sensitive Species.

The analysis below provides a table of those species evaluated for impacts within each section (Lake Powell, Glen Canyon Dam to Lake Mead, Lake Mead, and Hoover Dam to the SIB). The following analysis addresses only those species found in each section with habitat that could be affected by proposed operations within the analysis time frame through December 2026.

Summary

The types of impacts associated with each alternative are similar, as described above, as alternatives only vary by magnitude and timing of effects. The No Action Alternative would result in increased impacts on special status species at Lake Powell and Lake Mead compared with Action Alternatives 1 and 2. With no modifications to water management to address worsening drought conditions, water elevations would likely decrease over time as water resources become depleted in Lake Powell and Lake Mead to sustain flows in the Colorado River below Glen Canyon Dam to Lake Mead and the Hoover Dam to the SIB sections. The retention of water in Lake Powell under Action Alternatives 1 and 2 provides for high-flow events that may mitigate some impacts in the Glen Canyon Dam to Lake Mead section, making Action Alternatives 1 and 2 preferable to the No Action Alternative for terrestrial wildlife.

In most potential hydrologic futures (**Section 3.6.2**), impacts on special status species in the Colorado River below the Hoover Dam to the SIB section would be greater under Action Alternatives 1 and 2 compared with the No Action Alternative, as water flows are reduced to these sections to maintain higher water elevations in Lake Powell and Lake Mead.

In some of the driest potential hydrologic futures (**Section 3.6.2**, **Figure 3-8**), Lake Mead hits dead pool in early 2026. Under the No Action Alternative, no contingencies are in place to prevent Lake Mead from reaching dead pool. This would result in catastrophic impacts on the Hoover Dam to SIB section, as no water could be released beyond the inflows (run of the river operations). Action Alternatives 1 and 2 have contingencies in place to reduce flows should Lake Mead or Lake Powell be at risk of reaching dead pool, to ensure water delivery in all sections (**Chapter 2**).

The No Action Alternative would generally result in greater impacts on fish compared with Action Alternatives 1 and 2 in moderate to wet years. Under the No Action Alternative, the elevations of Lake Powell and Lake Mead would continue to decline, likely providing more suitable conditions for nonnative fish in both reservoirs. Although this could benefit game fish populations, it could also result in more predation and competition for native and listed fish species. Under the No Action Alternative, releases from Glen Canyon Dam and Hoover Dam would also decrease and reduce habitat for native and listed fish species downstream. Although these lower warmer releases may benefit subadults and adults of native fish species, these lower releases would likely benefit nonnative fish that are predators and competitors of native and listed fish species.

Under Action Alternatives 1 and 2, the elevations of Lake Powell and Lake Mead are expected to remain relatively stable (relative to the steady declines of the No Action Alternative), maintaining the newly established riverine habitat in the Colorado River and San Juan River inflows that are being used by endangered Colorado pikeminnow and razorback sucker. Releases from Glen Canyon Dam under Action Alternatives 1 and 2 would also remain more consistent (steady declines) than under the No Action Alternative (with a large drop off in 2026), providing more stable habitats for the early life stages of humpback chub, razorback sucker, flannelmouth sucker, and bluehead sucker in the Colorado River. However, depending on annual water supply, releases from Glen Canyon and Hoover Dams would potentially decrease under Action Alternatives 1 and 2 by up to 4.000 maf or more, compared with the No Action Alternative. Such reductions under Action Alternatives 1 and 2 would thus be less stable and result in more reductions in habitat for native and listed fish species than the No Action Alternative.

Both Action Alternatives 1 and 2 would have greater impacts than the No Action Alternative in the driest of potential hydrological futures. Both action alternatives would result in increased entrainment of smallmouth bass through Glen Canyon Dam, increased smallmouth bass population growth, and potentially more interactions between native and nonnative fish resulting in increased predation.

Overall, the No Action Alternative would result in greater impacts on fish compared with Action Alternative 1 and Action Alternative 2. Declining reservoir elevations in Lake Powell and Lake Mead have exposed deltaic sediments through which the Colorado River has carved a new channel. In Lake Powell, new channels—each about 30 miles long—have formed in the Colorado River and the San Juan River inflow. These have allowed for downstream expansions of the endangered Colorado pikeminnow and razorback sucker below the full pool elevation of Lake Powell. In Lake Mead, a new river channel of about 40 miles in length has been carved from Separation Canyon to Pearce Ferry, enabling the establishment of a new population of humpback chub. Under the No Action Alternative, lake elevations would continue to decline; these riverine channels would continue to expand and create more habitat for the benefit of the species. Under Action Alternatives 1 and 2, reservoir elevations would remain relatively stable, and habitat would also remain stable.

No Action Alternative

Lake Powell

In some of the driest potential hydrologic futures (**Section 3.6.2**, **Figure 3-5**), Lake Powell elevations are projected to decline in the summer 2023 and continue to decline through 2026.

Bald eagles and American white pelicans are the only special status species that utilize open-water habitat for foraging that have the potential to be impacted (**Table 3-31**, also see **Appendix E**, Table of Sensitive Species). Open-water habitat is expected to decline in Lake Powell during the analysis period. This could reduce foraging opportunities for these species. However, as a scavenger species, bald eagles, as well as golden eagles and California condors, may experience short-term benefits, as some carrion may become available during low water periods.

Foraging habits vary widely by species, but many bats forage for insects over open water and riparian vegetation. Many insects use wet areas and riparian vegetation for breeding. Loss of habitat for insects could reduce their populations, thereby reducing foraging opportunities for bats. Therefore, the No Action Alternative may impact individuals, as described in the 2007 FEIS (Reclamation 2007), but it would not likely lead to population declines for bats.

Arizona toads at Lake Powell rely on riparian habitats that are disconnected from the main body of the lake at lower lake levels and maintained by springs or inflows rather than water from the lake. As water levels drop, the distance from the water's edge to existing riparian habitat would increase, further disconnecting these habitats from the lake (Pedersen 2023). This would result in positive impacts on amphibians in these habitats due to a further disconnect from nonnative predatory fish. Therefore, the No Action Alternative may beneficially impact individuals of these species.

Table 3-31
Special Status Species with Records at Lake Powell and Potential Habitat Impacts

Common Name	Scientific Name	Status	Potential Impacts
Colorado pikeminnow	*Ptychocheilus lucius*	Endangered	Habitat expansion due to declining lake levels as result of increased riverine habitat
Razorback sucker	*Xyrauchen texanus*	Endangered	Habitat expansion due to declining lake levels as result of increased riverine habitat
Flannelmouth sucker	*Catostomus latipinnis*	BLM AZ BLM UT	Habitat expansion due to declining lake levels as result of increased riverine habitat
Bluehead sucker	*Catostomus discobolus*	BLM AZ BLM UT	Habitat expansion due to declining lake levels as result of increased riverine habitat
American white pelican	*Pelicanus erythrorhynchos*	BLM UT	Changes to open-water habitat availability, impacting foraging habitat
Bald eagle	*Haliaeetus leucocephalus*	BLM AZ BLM NV BLM UT	Changes to water levels, impacting foraging habitat
California condor	*Gymnogyps californianus*	BLM AZ	Changes to water levels potentially increasing scavenging opportunities
Golden eagle	*Aquila chrysaetos*	BLM UT BLM AZ	Changes to water levels potentially increasing scavenging opportunities
Allen’s big-eared bat	*Idionycteris* (=*Plecotus*) *phyllotis*	BLM AZ BLM NV BLM UT	Changes to riparian habitat availability, impacting foraging habitat
Big brown bat	*Eptesicus fuscus*	BLM NV	Changes to riparian habitat availability, impacting foraging habitat
California myotis	*Myotis californicus*	BLM NV	Changes to riparian habitat availability, impacting foraging habitat
Canyon bat	*Parastrellus hesperus*	BLM NV	Changes to riparian habitat availability, impacting foraging habitat
Cave myotis	*Myotis velifer*	BLM AZ BLM NV	Changes to riparian habitat availability, impacting foraging habitat
Fringed myotis	*Myotis thysanodes*	BLM UT BLM NV	Changes to riparian habitat availability, impacting foraging habitat
Mexican free-tailed bat	*Tadarida brasiliensis*	BLM NV	Changes to riparian habitat availability, impacting foraging habitat

Common Name	Scientific Name	Status	Potential Impacts
Pale Townsend's big-eared bat	*Corynorhinus townsendii pallescens*	BLM AZ	Changes to riparian habitat availability, impacting foraging habitat
Silver-haired bat	*Lasionycteris noctivagans*	BLM NV	Changes to riparian habitat availability, impacting foraging habitat
Townsend's big-eared bat	*Corynorhinus townsendii*	BLM AZ BLM CA BLM NV BLM UT	Changes to riparian habitat availability, impacting foraging habitat
Yuma myotis	*Myotis yumanensis*	BLM CA BLM NV	Changes to riparian habitat availability, impacting foraging habitat
Arizona toad	*Anaxyrus microscaphus*	BLM AZ BLM UT BLM NV	Changes in water levels, beneficially impacting breeding and foraging habitat by reducing predation

For species utilizing riparian areas along the waterline of Lake Powell, as water levels drop, the distance from the water's edge to existing riparian habitat would increase, potentially desiccating existing vegetation and reducing habitat quality until riparian vegetation grows along the newly established waterline. Newly exposed bank would likely be colonized by plant species that can establish quickly, which often include invasive species such as tamarisk (see the vegetation section). These fast-establishing plants would limit the impacts of increased distances to the water's edge for species utilizing these habitats.

Declining lake levels would likely expand or increase habitat for Colorado pikeminnow, razorback sucker, flannelmouth sucker, and bluehead sucker in the inflows to Lake Powell as riverine habitat would increase in the San Juan River and Colorado River inflows.

Glen Canyon Dam to Lake Mead

From 2023 to early 2026, impacts on special status species would be similar to those described in the 2007 FEIS (Reclamation 2007) except for special status fish, as discussed below. The following discussion for non-fish species pertains to 2026, when flows are projected to decrease and habitat declines would be expected to occur if water elevations continue to decrease.

Bald eagles are the only special status species that utilizes open-water habitat for foraging that has the potential to be impacted by project operations (**Table 3-32**; see also **Appendix E**, Table of Sensitive Species). Open-water habitat is expected to decline in the Glen Canyon Dam to Lake Mead section during the analysis period. This could reduce foraging opportunities for this species. However, as a scavenger species, bald eagles may experience short-term benefits, as some carrion may become available during low water periods.

Table 3-32
Special Status Species with Records between Glen Canyon Dam and Lake Mead and Potential Habitat Impacts

Common Name	Scientific Name	Status	Potential Impacts
Razorback sucker	*Xyrauchen texanus*	Endangered	• Shoreline habitat reduction due to reduced flows • Warmer water temperatures and lower lake Powell elevation may benefit fish arasite • Cold water temperature shock from rapid bypass water releases below elevation 3,490 feet • Potential expansion of nonnative smallmouth bass through entrainment and warmer water temperatures which may increase potential interactions with nonnative species
Humpback chub	*Gila cypha*	Threatened	• Shoreline habitat reduction due to reduced flows • Warmer water temperatures and lower lake Powell elevation may benefit fish arasite • Cold water temperature shock from rapid bypass water releases below elevation 3,490 feet • Potential expansion of nonnative smallmouth bass through entrainment and warmer water temperatures which may increase potential interactions with nonnative species
Flannelmouth sucker	*Catostomus latipinnis*	BLM AZ BLM UT	• Shoreline habitat reduction due to reduced flows • Potential expansion of nonnative smallmouth bass through entrainment and warmer water temperatures which may increase potential interactions with nonnative species

Common Name	Scientific Name	Status	Potential Impacts
Bluehead sucker	*Catostomus discobolus*	BLM AZ BLM UT	• Shoreline habitat reduction due to reduced flows • Potential expansion of nonnative smallmouth bass through entrainment and warmer water temperatures which may increase potential interactions with nonnative species
Bald eagle	*Haliaeetus leucocephalus*	BLM AZ BLM NV BLM UT	Changes to water levels, impacting foraging habitat
California black rail	*Laterallus jamaicensis coturniculus*	BLM AZ BLM CA	Changes to riparian habitat availability, impacting foraging and nesting habitat
Yuma Ridgeway's rail	*Rallus obsoletus yumaniensis*	Endangered BLM AZ BLM CA BLM NV	Changes to riparian habitat availability, impacting foraging and nesting habitat
Allen's lappet-browed bat	*Idionycteris phyllotis*	BLM AZ	Changes to riparian habitat availability and prey diversity, impacting foraging habitat
Arizona myotis	*Myotis occultus*	BLM AZ	Changes to riparian habitat availability and prey diversity, impacting foraging habitat
Big brown bat	*Eptesicus fuscus*	BLM NV	Changes to riparian habitat availability, impacting foraging habitat
California leaf-nosed bat	*Macrotus californicus*	BLM AZ BLM NV	Changes to riparian habitat availability and prey diversity, impacting foraging habitat
California myotis	*Myotis californicus*	BLM NV	Changes to riparian habitat availability and prey diversity, impacting foraging habitat
Canyon bat	*Parastrellus hesperus*	BLM NV	Changes to riparian habitat availability and prey diversity, impacting foraging habitat
Cave myotis	*Myotis velifer*	BLM AZ BLM NV	Changes to riparian habitat availability and prey diversity, impacting foraging habitat
Greater western bonneted bat	*Eumops perotis*	BLM AZ	Changes to riparian habitat availability and prey diversity, impacting foraging habitat
Mexican free-tailed bat	*Tadarida brasiliensis*	BLM NV	Changes to riparian habitat availability, impacting foraging habitat
Pale Townsend's big-eared bat	*Corynorhinus townsendii pallescens*	BLM AZ	Changes to riparian habitat availability and prey diversity, impacting foraging habitat
Spotted bat	*Euderma maculatum*	BLM AZ BLM NV BLM UT	Changes to riparian habitat availability and prey diversity, impacting foraging habitat
Silver-haired bat	*Lasionycteris noctivagans*	BLM NV	Changes to riparian habitat availability and prey diversity, impacting foraging habitat
Western mastiff bat	*Eumops perotis*	BLM AZ BLM NV	Changes to riparian habitat availability and prey diversity, impacting foraging habitat

Common Name	Scientific Name	Status	Potential Impacts
Yuma myotis	*Myotis yumanensis*	BLM CA BLM NV	Changes to riparian habitat availability and prey diversity, impacting foraging habitat
Monarch butterfly	*Danaus plexippus plexippus*	BLM NV ESA Candidate	Changes to riparian habitat availability, impacting breeding and foraging habitat

Species that use riparian habitat and shallow water along the banks, such as the California black rail and Yuma Ridgway's rail, could be impacted through changes in habitat availability. As water levels drop, the distance from the water's edge to existing riparian habitat would increase, potentially desiccating existing vegetation and reducing habitat quality until riparian vegetation grows along the newly established waterline. Newly exposed bank would likely be colonized by plant species that can establish quickly, which often include invasive species such as tamarisk (see the vegetation section). These fast-establishing plants would limit the impacts of increased distances to the water's edge for species utilizing these habitats.

Bats often forage for insects over open water and riparian vegetation. Many insects use wet areas and riparian vegetation for breeding. Loss of habitat for insects could reduce their populations, thereby reducing foraging opportunities for bats. Lower water levels could also impact invertebrate biodiversity and have subsequent effects on bat species. Bat species could be impacted by changing prey availability causing reduced fitness and increased susceptibility to white-nose syndrome (Holm et al. 2023). Potential reduced fitness and greater susceptibility to disease could impact bat populations. Therefore, the No Action Alternative may impact individuals, as described in the 2007 FEIS (Reclamation 2007), and may lead to population declines for bats.

Monarch butterflies utilize meadows and areas with nectar-producing flowers as foraging habitat. They rely on milkweed (*Ascelpias* spp.) for egg laying. This habitat type is found throughout the United States, Canada, and Mexico, and some milkweeds are riparian species (NatureServe 2023). It is unlikely that high-quality foraging habitat for this species would be impacted by changes in flows, but some milkweeds are likely present in riparian and backwater areas. A reduction in flows may cause water stress to milkweeds and other flowering plants. Therefore, the No Action Alternative may impact individuals and could exacerbate downward trends for this species.

Adult humpback chub use deepwater recirculating eddies that are not affected by flow changes; however, age-0 and juveniles use shoreline talus habitats that could be negatively affected by reduced flows, depending on the amount of water released. Although the core reproducing population of humpback chub is still in the Little Colorado River, a more recent aggregation in the Western Grand Canyon has been detected. This is likely due to the warmer water temperatures over the last 10 years and the formation of Pearce Ferry Rapid as a partial barrier to upstream movement of nonnative predators. Surveys from 2022 estimated the abundance of humpback chub in the Western Grand Canyon as 40,000–60,000 between Havasu Rapid and Pearce Ferry (USGS 2023e). Because there are so few razorback suckers in the Grand Canyon, they are unlikely to be affected by reduced flows. However, if the flows were to result in a change to Pearce Ferry Rapid, nonnative fish could move into the Grand Canyon.

The interaction of flow, water temperature, and turbidity are likely to impact nonnative fish as well. Reduced flows and warming water temperatures are likely to provide more suitable conditions for spawning, egg incubation, and survival of young of warmwater species. Many of these species (e.g., channel catfish, bullheads, green sunfish, smallmouth bass, and largemouth bass) prey on different life stages of the native fish and could impose additional stressors on the population of humpback chub. Warmer temperatures, however, may also reduce foraging efforts by rainbow trout and brown trout that are the cold-water predators of humpback chub.

Spawning and rearing habitat in the lower end of Grand Canyon above the Lake Mead inflow may be reduced for humpback chub due to decreasing flows. Cobble bars at tributary inflows like Spencer Creek may be used for spawning and would be desiccated by reduced flows. Also, backwater habitats in lower Grand Canyon that are used by the young would be desiccated by reduced flows. Additionally, warmer water temperatures may increase the razorback sucker's and humpback chub's exposure to parasites that are detrimental to the species, such as the Asian tapeworm and anchorworm. Warmer water temperatures may also provide more suitable conditions for spawning and survival of young nonnative fish that are predators of native fish species.

Reduction in flows through Grand Canyon could also negatively affect the razorback sucker. Lower flows would make it nearly impossible for adults to move from Lake Mead upstream past the Pearce Ferry Rapid and into the lower Grand Canyon. This barrier would also potentially reduce upstream movement by other native and nonnative fish. The Colorado River in Grand Canyon could serve as a potential spawning area to the razorback sucker population from Lake Mead. This impediment would reduce the number of razorback suckers in the Colorado River through the Grand Canyon and impede the establishment of a population in this reach. This would negatively affect recovery of the species.

Under the No Action Alternative, the GTMax Model shows that releases through the penstocks at Glen Canyon Dam would drop to zero from January through April 2024, and water would need to be released through the river outlet works. At low levels of Lake Powell, release temperatures are projected to be as high as 20˚C) and switching to releasing water through the river outlet works would mean much colder release temperatures of 10–12˚C. This cold-release regime would be similar to releases prior to 2004, when the reservoir was above 3,600-feet (1,097-meter) (Valdez et al. 2015). There could be an effect, however, on fish populations downstream of Glen Canyon Dam if water temperature releases rapidly shift from warm water to cold water. This colder release could temperature shock juvenile and adult rainbow trout in the Lees Ferry reach as well as eggs and fry that would be in the gravel beds at this time. The water would warm longitudinally downstream, and the impact would be minimal on juvenile and adult humpback chub, razorback sucker, flannelmouth sucker, and bluehead sucker. However, sudden colder releases could temperature shock eggs, larvae, and age-0 of these species.

Lake Mead

Bald eagles are the only special status species that utilize open-water habitat for foraging that have the potential to be impacted by project operations (**Table 3-33**, see also **Appendix E**, Table of Sensitive Species). Open-water habitat is expected to decline in Lake Mead during the analysis period. This could reduce foraging opportunities for this species. However, as a scavenger species, bald eagles may experience short-term benefits, as some carrion may become available during low water periods.

Table 3-33
Special Status Species with Records at Lake Mead and Potential Habitat Impacts

Common Name	Scientific Name	Status	Potential Impacts
Razorback sucker	*Xyrauchen texanus*	Endangered	Changes to water levels, impacting spawning and rearing habitat and increased predation on young
Humpback chub	*Gila cypha*	Threatened	Changes to water levels, impacting spawning and rearing habitat and increased predation on young
Flannelmouth sucker	*Catostomus latipinnis*	BLM AZ BLM UT	Changes to water levels, impacting spawning and rearing habitat and increased predation on young
Bluehead sucker	*Catostomus discobolus*	BLM AZ BLM UT	Changes to water levels, impacting spawning and rearing habitat and increased predation on young
Bald eagle	*Haliaeetus leucocephalus*	BLM AZ BLM NV BLM UT	Changes to water levels, impacting foraging habitat
Southwestern willow flycatcher	*Empidonax traillii extimus*	Endangered BLM AZ BLM CA BLM NV	Changes to riparian habitat availability, impacting foraging and nesting habitat
Yuma Ridgway's rail	*Rallus obsoletus yumaniensis*	Endangered BLM AZ BLM CA BLM NV	Changes to riparian habitat availability, impacting foraging and nesting habitat
Allen's big-eared bat	*Idionycteris (=Plecotus) phyllotis*	BLM AZ BLM NV BLM UT	Changes to riparian habitat availability, impacting foraging habitat
Arizona myotis	*Myotis occultus*	BLM AZ	Changes to riparian habitat availability, impacting foraging habitat
Big brown bat	*Eptesicus fuscus*	BLM NV	Changes to riparian habitat availability, impacting foraging habitat
Big free-tailed bat	*Nyctinomops macrotis*	BLM NV	Changes to riparian habitat availability, impacting foraging habitat
California leaf-nosed bat	*Macrotus californicus*	BLM AZ BLM NV	Changes to riparian habitat availability, impacting foraging habitat
California myotis	*Myotis californicus*	BLM NV	Changes to riparian habitat availability, impacting foraging habitat
Canyon bat	*Parastrellus hesperus*	BLM NV	Changes to riparian habitat availability, impacting foraging habitat
Cave myotis	*Myotis velifer*	BLM AZ BLM NV	Changes to riparian habitat availability and prey diversity, impacting foraging habitat
Desert bighorn sheep	*Ovis canadensis nelsoni*	BLM CA	Exposed soft sediments trapping individuals and causing mortality
Fringed myotis	*Myotis thysanodes*	BLM UT BLM NV	Changes to riparian habitat availability, impacting foraging habitat

Common Name	Scientific Name	Status	Potential Impacts
Hoary bat	*Lasiurus cinereus*	BLM NV	Changes to riparian habitat availability, impacting foraging habitat
Mexican free-tailed bat	*Tadarida brasiliensis*	BLM NV	Changes to riparian habitat availability, impacting foraging habitat
Pale Townsend's big-eared bat	*Corynorhinus townsendii pallescens*	BLM AZ	Changes to riparian habitat availability, impacting foraging habitat
Pallid bat	*Antrozous pallidus*	BLM NV	Changes to riparian habitat availability, impacting foraging habitat
Silver-haired bat	*Lasionycteris noctivagans*	BLM NV	Changes to riparian habitat availability, impacting foraging habitat
Townsend's big-eared bat	*Corynorhinus townsendii*	BLM AZ BLM CA BLM NV BLM UT	Changes to riparian habitat availability, impacting foraging habitat
Western mastiff bat	*Eumops perotis*	BLM AZ BLM NV	Changes to riparian habitat availability, impacting foraging habitat
Western red bat	*Lasiurus blossevillii*	BLM NV BLM UT	Changes to riparian habitat availability, impacting foraging habitat
Western small-footed myotis	*Myotis ciliolabrum*	BLM CA BLM NV	Changes to riparian habitat availability, impacting foraging habitat
Yuma myotis	*Myotis yumanensis*	BLM CA BLM NV	Changes to riparian habitat availability, impacting foraging habitat
Lowland leopard frog	*Rana yavapaiensis*	BLM AZ BLM CA	Changes to riparian habitat availability and water levels, impacting breeding and foraging habitat
Gold butte moss	*Ceratodon purpureus*	BLM NV	Changes to hydrology, impacting suitable habitat
Mojave poppy bee	*Perdita meconis*	BLM NV	Changes to hydrology, impacting suitable habitat
Monarch butterfly	*Danaus plexippus plexippus*	BLM NV ESA Candidate	Changes to riparian habitat availability, impacting breeding and foraging habitat
Mokiak milkvetch	*Astragalus mokiacensis*	BLM NV	Changes to hydrology, impacting suitable habitat
Sticky buckwheat	*Eriogonum viscidulum*	BLM AZ BLM NV	Changes to hydrology, impacting suitable habitat

Species that utilize riparian habitat and shallow water along the banks, such as Yuma Ridgway's rail or lowland leopard frog, could be impacted through changes in habitat availability. Impacts on riparian habitats used by these species would be similar to those described above in the Lake Powell section. Impacts on bat species would be similar to those described in the Glen Canyon Dam to Lake Mead section.

Southwestern willow flycatchers rely on dense riparian vegetation and large cottonwood trees for nesting and foraging habitat (NatureServe 2023). These habitats would take longer to reestablish along the new shoreline, potentially impacting southwestern willow flycatchers. This species would likely adjust its distribution to the unaffected tributaries that support riparian vegetation until new riparian vegetation reestablished along Lake Mead. The No Action Alternative may impact individuals, as described in the 2007 FEIS (Reclamation 2007), but it would not likely lead to population declines of southwestern willow flycatchers.

Impacts on bats would be similar to those described in the Lake Powell section of the No Action Alternative. In areas where new sediments are exposed, larger animals may become stuck in deep mud and die. This is currently occurring and may be exacerbated with declining lake levels under this alternative.

Special status plant species that grow in riparian habitat or in wet soils could be impacted through changes in water availability. Some plant species have deep roots and can tolerate changes in water levels, while others are sensitive to change. Species that can tolerate drought periods and lower water levels may experience an increase in habitat availability as water levels recede, while species sensitive to these changes would likely experience a decrease in habitat availability.

Declining lake elevations would increase riverine habitat for humpback chub, razorback sucker, flannelmouth sucker, and bluehead sucker in the Colorado River inflow. While this may be a benefit for overall riverine habitat, declining elevation would also reduce shoreline spawning habitat for razorback sucker and nursery habitat for larvae in embayments and vegetated shorelines. Reduced lake elevation in spring would bring the lake below levels of emergent vegetation that are used by the larvae and age-0 for shelter and feeding. This would reduce survival and recruitment for the species.

Hoover Dam to the SIB

Given the decrease in water elevations projected in Lake Mead, less water would be available for release into this section and ultimately no water would be released from Hoover Dam as Lake Mead reached dead pool. As shortages increase over time, riparian vegetation along the lower Colorado River would likely decrease.

In some of the driest potential hydrologic futures (**Section 3.6.2**, **Figure 3-8**), Lake Mead hits dead pool in early 2026. At this point, no water would be released from Lake Mead into the Hoover Dam to SIB section, severely limiting water resources in this section. Water in this section would be limited to inflows below Hoover Dam. It is likely that these inflows would be insufficient to support aquatic special status species populations, leading to extirpation or extreme reductions in population numbers. In this scenario, scavenger species such as bald eagles, golden eagles, and California condors may experience short-term benefits, as substantial amounts of carrion would be available.

Bald eagles are the only special status species that utilize open-water habitat for foraging that have the potential to be impacted by project operations (**Table 3-34**, see also **Appendix E**, Table of Sensitive Species). Open-water habitat is expected to decline in the Hoover Dam to SIB section during the analysis period. This could reduce foraging opportunities for this species. However, as a scavenger species, bald eagles, as well as golden eagles, may experience short-term benefits, as some carrion may become available during low water periods.

Table 3-34
Special Status Species with Records between Hoover Dam and the SIB and Potential Habitat Impacts

Common Name	Scientific Name	Status	Potential Impacts
Razorback sucker	*Xyrauchen texanus*	Endangered	Changes to water levels, impacting spawning and nursery habitat
Bonytail chub	*Gila elegans*	Threatened	Changes to water levels, impacting spawning and nursery habitat
Flannelmouth sucker	*Catostomus latipinnis*	BLM AZ BLM UT	Changes to water levels, impacting spawning and nursery habitat
Desert pupfish	*Cyprinodon macularius*	Endangered	Changes to water levels, impacting spawning and nursery habitat
Arizona bell's vireo	*Vireo bellii arizonae*	BLM CA	Changes to water levels, impacting foraging and nesting habitat
Bald eagle	*Haliaeetus leucocephalus*	BLM AZ BLM NV BLM UT	Changes to water levels, impacting foraging habitat
California black rail	*Laterallus jamaicensis coturniculus*	BLM AZ BLM CA	Changes to riparian habitat availability, impacting foraging and nesting habitat
Crissal thrasher	*Toxostoma crissale*	BLM CA	Changes to water levels, impacting foraging and nesting habitat
Gila woodpecker	*Melanerpes uropygialis*	BLM CA	Changes to water levels, impacting foraging and nesting habitat
Gilded flicker	*Colaptes chrysoides*	BLM AZ BLM CA	Changes to water levels, impacting foraging and nesting habitat
Golden eagle	*Aquila chrysaetos*	BLM UT BLM AZ	Changes to water levels potentially increasing scavenging opportunities
Lucy's warbler	*Vermivora luciae*	BLM CA	Changes to water levels, impacting foraging and nesting habitat
Mountain plover	*Charadrius montanus*	BLM CA	Changes to water levels, impacting foraging habitat
Southwestern willow flycatcher	*Empidonax traillii extimus*	Endangered BLM AZ BLM CA BLM NV	Changes to riparian habitat availability, impacting foraging and nesting habitat
Tricolored blackbird	*Agelaius tricolor*	BLM CA	Changes to riparian habitat availability, impacting foraging and nesting habitat
Western yellow-billed cuckoo	*Coccyzus americanus*	Threatened BLM AZ BLM CA BLM NV	Changes to riparian habitat availability, impacting foraging and nesting habitat
White-tailed kite	*Elanus leucurus*	BLM CA	Changes to riparian habitat availability, impacting foraging habitat

Common Name	Scientific Name	Status	Potential Impacts
Yuma Ridgway's rail	*Rallus obsoletus yumaniensis*	Endangered BLM AZ BLM CA BLM NV	Changes to riparian habitat availability, impacting foraging habitat
Arizona myotis	*Myotis occultus*		Changes to riparian habitat availability, impacting foraging habitat
Big brown bat	*Eptesicus fuscus*	BLM NV	Changes to riparian habitat availability, impacting foraging habitat
California leaf-nosed bat	*Macrotus californicus*	BLM AZ BLM NV	Changes to riparian habitat availability, impacting foraging habitat
California myotis	*Myotis californicus*	BLM NV	Changes to riparian habitat availability, impacting foraging habitat
Cave myotis	*Myotis velifer*	BLM AZ BLM NV	Changes to riparian habitat availability, impacting foraging habitat
Long-eared myotis	*Myotis evotis*	BLM CA	Changes to riparian habitat availability, impacting foraging habitat
Mexican free-tailed bat	*Tadarida brasiliensis*	BLM NV	Changes to riparian habitat availability, impacting foraging habitat
Pale Townsend's big-eared bat	*Corynorhinus townsendii pallescens*	BLM AZ	Changes to riparian habitat availability, impacting foraging habitat
Pallid bat	*Antrozous pallidus*	BLM NV	Changes to riparian habitat availability, impacting foraging habitat
Spotted bat	*Euderma maculatum*	BLM AZ BLM NV BLM UT	Changes to riparian habitat availability, impacting foraging habitat
Silver-haired bat	*Lasionycteris noctivagans*	BLM NV	Changes to riparian habitat availability, impacting foraging habitat
Townsend's big-eared bat	*Corynorhinus townsendii*	BLM AZ BLM CA BLM NV BLM UT	Changes to riparian habitat availability, impacting foraging habitat
Western mastiff bat	*Eumops perotis*	BLM AZ BLM NV	Changes to riparian habitat availability, impacting foraging habitat
Western small-footed myotis	*Myotis ciliolabrum*	BLM CA BLM NV	Changes to riparian habitat availability, impacting foraging habitat

Common Name	Scientific Name	Status	Potential Impacts
Yuma myotis	*Myotis yumanensis*	BLM CA BLM NV	Changes to riparian habitat availability, impacting foraging habitat
Arizona toad	*Anaxyrus microscaphus*	BLM UT BLM NV	Changes to riparian habitat availability and water levels, impacting breeding and foraging habitat
Couch's spadefoot	*Scaphiopus couchii*	BLM CA	Changes to riparian habitat availability, impacting foraging and breeding habitat
Lowland leopard frog	*Rana yavapaiensis*	BLM AZ BLM CA	Changes to riparian habitat availability and water levels, impacting breeding and foraging habitat
Northern Mexican garter snake	*Thamnophis eques megalops*	Threatened	Changes to riparian habitat availability and water levels, impacting breeding and foraging habitat
Relict leopard frog	*Rana onca*	BLM AZ BLM NV	Changes to riparian habitat availability and water levels, impacting breeding and foraging habitat
Monarch butterfly	*Danaus plexippus plexippus*	BLM NV ESA Candidate	Changes to riparian habitat availability and water levels, impacting breeding and foraging habitat
Mojave tarplant	*Deinandra mohavensis*	BLM CA	Changes to hydrology, impacting suitable habitat
Parish's meadowfern	*Limnanthes alba ssp. parishii*	BLM CA	Changes to hydrology, impacting suitable habitat
Variegated dudleya	*Dudleya variegata*	BLM CA	Changes to hydrology, impacting suitable habitat

Impacts on monarch butterflies would be similar to those described in the Glen Canyon to Lake Mead section.

Species that utilize riparian vegetation, such as many of the birds and amphibians listed in **Table 3-34**, could benefit initially as new sediments are exposed and riparian habitat grows into areas that were previously inundated. However, beyond the 2026 analysis window, long-term impacts would likely be detrimental, given the level of water reductions expected in this reach.

Northern Mexican garter snakes have been detected at Havasu NWR and the Bill Williams NWR. This species was previously considered extirpated from these areas. Given the newly discovered populations, it is assumed that this species could be present anywhere along the Hoover Dam to the SIB section. This species relies on wetland and aquatic habitat for foraging on small fish and amphibians (Northern Arizona University 2023). Reduced water elevations could impact riparian habitat and wetlands used by Northern Mexican garter snakes.

Impacts on bat species would be similar to those described in the Lake Powell section. Impacts on special status plant species would be similar to those described in the Lake Mead section.

Overall, reductions in water availability would have the same impacts on native fish through reduction of habitat such as backwater and floodplains for larval razorback sucker, bonytail chub, and flannelmouth sucker.

Action Alternative 1

Lake Powell

Once Action Alternative 1 was implemented, water elevations would gradually increase through 2026, and are projected to be higher than the No Action Alternative. This increase in water elevation could result in the loss of some riparian habitat that has recently established along the lake during lower water periods. Terrestrial special status species in this section are not particularly riparian dependent and increased water levels would increase foraging acreage for open-water species. Therefore, impacts on terrestrial special status species in this section would be similar to those described in the 2007 FEIS (Reclamation 2007) and the No Action Alternative, with a decreasing magnitude of effects as lake levels increase.

Under Action Alternative 1, the elevation of Lake Powell would not be allowed to drop below the minimum power pool elevation of 3,490 feet (1,063 meters). This alternative would fundamentally stabilize lake levels and would maintain extended fish habitat in the Colorado River and San Juan River inflows that are occupied by Colorado pikeminnow, razorback sucker, and flannelmouth sucker. The extended habitat would be a benefit to these species, and this alternative would help maintain that habitat. There may be some reduction of shoreline riverine habitat used by young fish as the reservoir elevation is increased toward 2026. This is due to the rise in elevation of the lake and encroachment upon riverine habitat that was created from low levels in the lake in the inflow areas; however, the reduction in shoreline habitat is not quantified. About 30 miles of inflow riverine habitat has been created by lowered lake elevations, but the amount that would be inundated by an increasing lake elevation is unknown.

Glen Canyon Dam to Lake Mead

Once Action Alternative 1 was implemented, releases from Lake Powell would be reduced, which would result in lower water elevations in this section compared with the No Action Alternative (**Table 3-30**).

See the vegetation section above for impacts related to native and nonnative species that provide habitat for special status species. While still providing some habitat, nonnative plant species provide lower-quality habitat than native species and can lead to monotypic habitat types that support fewer wildlife species (NatureServe 2023).

Impacts on terrestrial wildlife would be similar to those described for the No Action Alternative with an increasing magnitude of effects as water elevations begin to decrease and nonnative plant cover increases. However, the greater likelihood for high-flow experiments under this alternative, relative to the No Action Alternative, reduces some of the impacts described under that alternative. Specifically, the likelihood of impacts on invertebrate diversity and subsequent prey availability effects could be reduced.

Under Action Alternative 1, releases from Lake Powell and through Glen Canyon Dam would not be allowed to drop below the minimum power pool elevation of 3490 feet. This would allow water to continue to be released in the Colorado River below Glen Canyon Dam, although at a reduced level in some years. In years when reduced flow occurred, reduced amount of shoreline habitat and backwaters would be available for use by age-0, juvenile, and subadult humpback chub. In the lower Grand Canyon, reduced flows could reduce availability of potential spawning areas for humpback chub, razorback sucker, and flannelmouth sucker, as well as backwaters used by the young of these species. Reduced river flows and lake elevation would also make it more difficult for adult razorback sucker to ascend Pearce Ferry Rapid and enter the Colorado River through Grand Canyon. This is already a rare occurrence, and increased difficulty would further limit the expansion of the species and negatively affect species recovery. Reductions in flow releases also may result in increased water temperatures, thereby creating better conditions for nonnative fish, such as smallmouth bass, and subsequently increasing the potential for predation on native species.

Lake Mead

Once Action Alternative 1 was implemented, water elevations would continue to gradually decrease to levels slightly below the No Action Alternative, but then would increase in 2025 to higher than the No Action Alternative. However, water elevations would remain lower in 2026 than 2022.

Therefore, impacts on special status species in this section would be similar to those described in the 2007 FEIS (Reclamation 2007) and the No Action Alternative, with a decreasing magnitude of effects as lake levels increase in 2025.

Hoover Dam to the SIB

After implementing Action Alternative 1, releases from Lake Mead would be reduced, which would result in lower water elevations in this section compared with the No Action Alternative. Impacts on riparian vegetation and terrestrial wildlife species would, therefore, be greater under Action Alternative 1 than the No Action Alternative in all but the driest potential hydrologic futures (**Section 3.6.2**, **Figure 3-8**). Furthermore, this alternative would lead to water shortages at existing irrigated riparian habitat mitigation areas, leading to reductions in available habitat for riparian species.

However, in the driest potential hydrologic futures (**Section 3.6.2**, **Figure 3-8**), where Lake Mead is projected to reach dead pool, water deliveries from Lake Mead would be reduced in advance to avoid reaching these levels. Should these adjustments prove successful, the scenario of no water passing through Hoover Dam would not occur. Water levels in the section between Hoover Dam and the SIB could be critically low, but there would still be flow in the river to support special status species at levels substantially greater than those described under the No Action Alternative.

Loss of fish habitat would be proportional to loss of backwater areas described by Reclamation in the backwater model. Razorback sucker and bonytail that are stocked in these backwaters would have less habitat when total volume of water is reduced.

Action Alternative 2

Action Alternative 2 includes modified water delivery priorities through Glen Canyon Dam compared with Action Alternative 1 and marginally increases the water supply to Lake Powell through releases of water from the Upper Basin reservoirs. This would result in marginally more water throughout the system compared with Action Alternative 1. These marginal increases could be meaningful in the driest potential hydrologic futures (**Section 3.6.2**), especially immediately downstream of Hoover Dam. Also, the changes in water allocations under this alternative, relative to Action Alternative 1, would result in more water in the Colorado River between Hoover Dam and the locations where water is diverted for uses in California. However, these differences are minimal when considering impacts on special status species. Therefore, overall impacts on special status species are similar to those described under Action Alternative 1 for all analysis sections, other than part of the Hoover Dam to SIB section, where impacts of Action Alternative 2 are reduced compared with Action Alternative 1.

Cumulative Effects

The Glen Canyon Dam/Smallmouth Bass flow options is the only cumulative action identified in **Section 3.5.1**. If one of the flow options were implemented, this action would cumulatively impact aquatic species within the Colorado River below Glen Canyon Dam to Lake Mead due to changes in the temperature of water released through Glen Canyon Dam. The intent of this cumulative action is to prevent the establishment of invasive smallmouth bass. Under all alternatives, the effects of this cumulative action would be beneficial for aquatic special status species unless water levels in Lake Powell reached minimum power pool levels. At this elevation, all flows passing through Glen Canyon Dam would be directed through the river outlet works out of necessity, nullifying this cumulative action.

There are two important points in the analysis of smallmouth bass effects by Yackulic (2023). First, under poor/drier hydrology, the action alternatives can increase the predator population by 500 percent, unless coupled with the smallmouth bass release strategies. Second, under the No Action Alternative and very poor hydrology, the smallmouth bass flow release strategies cannot be used; this is because the reservoir is below power pool. In the first year or two, the drop below power pool elevation (3,490 feet) would require releases from the river outlet works, thereby cooling the water and reducing the entrainment of smallmouth bass. However, after a year or two the reservoir level would decrease enough that the river outlet works would no longer release cool water. The thermocline (mesolimnion or middle warm oxygenated zone of the reservoir) moves down with the reservoir level; when it is in a range as low as 3,425 to 3,450 feet, the water is once again warm, and entrainment is possible again. Both of these dynamics are critical to understanding the interaction of reservoir elevation, dam releases, and water temperatures.

3.14 Recreation

3.14.1 Affected Environment

This SEIS builds on the 2007 FEIS, which identifies and describes in detail the following key recreation resources or issues:

- Shoreline public use
- Reservoir boating
- River and whitewater boating
- Sport fishing

This section provides updated information, data, and conditions for these resources since the publication of the 2007 FEIS. In addition, based on proposed changes to the flow rate of the Colorado River between Glen Canyon Dam and Lake Mead, the following recreation resource issue may also be affected:

- Ecotourism of previously buried ecosystems in Glen Canyon, which has become increasingly popular as Lake Powell recedes

Shoreline Public Use

The following sections describe shoreline public use associated with boating facilities (marinas, boat docks, and boat launch ramps), access to points of interest, and other opportunities within each Colorado River reach. Recreational boating in the study area depends on these major shoreline access points. While fluctuation in pool elevations is a normal aspect of reservoir operations, changes in pool elevations or increased variations or rates in pool elevation fluctuation could result in changes in operation costs and temporary closures. Below critical pool elevations and river flows, certain facilities may be rendered inoperable, or they may require relocation to maintain their operation. (Additional information on recreational boating and boating facilities can be found in the 2007 FEIS Section 3.12.1; the information is incorporated by reference.)

Lake Powell and Glen Canyon Dam

Lake Powell is entirely within the GCNRA, which receives approximately three to four million visitors each year (NPS 2023a). **Table 3-35** summarizes visitation to GCNRA for the most recent 6 years.

Table 3-35
Glen Canyon National Recreation Area Recreational Visitors

Year	Recreational Visitors
2017	4,574,940
2018	4,219,441
2019	4,330,563
2020	2,553,392
2021	3,144,318

Year	Recreational Visitors
2022	2,842,776

Source: NPS 2023a

Table 3-36 summarizes the total number of visits to GCNRA by visitor segment for 2022, the most recent year for which data are available.

Table 3-36
Glen Canyon National Recreation Area Visits by Visitor Segment for 2022

Recreation Visitors	Non-Recreation Visitors*	Concession Lodging	Tent Campers	RV Campers	Concession Camping	Backcountry Camping	Misc. Campers	Total Overnight Stays
2,842,776	23,322	23,636	9,647	10,799	2,286	2,308	518,772	567,449

Source: NPS 2023b

*The NPS defines reportable non-recreation visits to include:

- Persons going to and from inholdings across significant parts of park land
- Commuter and other through traffic using NPS-administered roads or waterways through a park for their convenience
- Tradespeople with business in the park
- Any civilian activity that is a part of or incidental to the pursuit of a gainful occupation (for example, guides)
- Government personnel (other than NPS employees) with business in the park
- Citizens using NPS buildings for civic or local government business, or attending public hearings
- Outside research activities (visits and overnights), if they are independent of NPS-legislated interests (for example, meteorological research) (NPS 2022a)

Lake Powell, with its many side canyons and related natural, cultural, and geologic resources, is the primary recreation feature of GCNRA. Recreation that occurs at Lake Powell includes swimming and sunbathing, power boating, waterskiing, fishing, off-beach activities associated with boat trips (such as hiking and exploring archaeological sites), house boating, personal watercraft use, canoeing, kayaking, sailing, wildlife viewing, photography, sightseeing, diving, and other activities. Visitors can enjoy camping opportunities ranging from going to remote and undeveloped campsites to going to fully developed campgrounds. Visitors can also see archaeologically and culturally important sites throughout the GCNRA.

Boating Facilities

Recreational boating is the most important recreational activity on Lake Powell, with nearly two million visitors accessing the reservoir by either private boat or rental (NPS 2023c). Specific boating facilities and reservoir elevations important to their operation are discussed in the 2007 FEIS. Water-based recreational facilities at Lake Powell include Wahweap, Halls Crossing, Bullfrog, and Antelope Point marinas. Since the publication of the 2007 FEIS, declining water levels have rendered the Dangling Rope Marina inoperable since 2021; this marina previously provided boating access to Rainbow Bridge National Monument. The Hite Launch Ramp has also been closed since 2012 due to the ramp being out of the water (NPS 2023d).

Changes to the shoreline affect the usability of boat launch ramps throughout the year, especially in warmer months. Launch ramp closures resulting from declining water levels have resulted in longer lines, limited parking, and congestion at boat ramps and docks (NPS 2023d).

In 2022, the NPS received $26 million in Disaster Supplemental Funding to provide additional boating access at Lake Powell. Design work is proceeding for a North Lake Powell ramp that reaches an elevation of 3,450 feet in the Stanton Creek area. The NPS is also working to develop schematic designs for the Antelope Point Public Ramp, Halls Crossing Public Ramp, and primitive ramp and take-out area at the Hite Marina. The NPS continues to seek funding necessary for potential reconstruction. The NPS is also continuing to seek funds to replace the services previously offered at Dangling Rope Marina, a long-term solution for lake access to Rainbow Bridge National Monument, and a Navigable Waterway Congestion Study in South Lake Powell (NPS 2023d).

Table 3-37
Critical Elevations for Lake Powell by Boating Facility

Lake Elevation (feet)	Impact and Facility
3,700	Full pool
3,645	Hite Marina would need to be reconfigured and possibly moved; Hite Public Launch Ramp closed
3,587	Antelope Point Public Ramp closed
3,580	Castle Rock Cut closed
3,562	Stateline Public Launch Ramp closed
3,553	Halls Crossing Marina would need to be reconfigured and possibly moved
3,551	Wahweap Main Ramp closed
3,530	Antelope Point Business Ramp closed
3,525	Bullfrog North Ramp closed
3,522	Stateline Auxiliary closed
3,490	Main Bullfrog Launch Ramp closed

Source: Personal communications with Heidie Grigg, GCNRA Acting Chief of External Affairs, NPS, on March 16, 2023

Access to Points of Interest

As previously mentioned, as of 2021 there is no longer dock access to the Rainbow Bridge National Monument shoreline. Access is limited to the Rainbow Bridge Trail. Visitors generally have to leave boats and small vessels at the shoreline and often traverse through mud, debris, sand, and water before reaching the established trail. While no longer connected to the shoreline, the Rainbow Bridge dock system is accessible with restroom facilities. The concessionaire-operated tours to the monument are no longer able to access the area, thus removing access for most GCNRA visitors. Visitors can also access Rainbow Bridge National Monument by obtaining a permit from the Navajo Nation Parks and Recreation Department to backpack for multiple days on Navajo Tribal lands from Navajo Mountain; however, this is not possible for many visitors (NPS 2021).

Harmful Algal Blooms

Warming water temperatures and increased inputs of nutrients from monsoonal storms create conditions that are more conducive to the growth of harmful algal blooms. Harmful algal blooms produce toxins that pose serious health risks to humans and animals (NPS 2019). (Water quality concerns are described in detail in **Section 3.8**.)

Quagga Mussel Shells on Shorelines

Quagga mussels were first detected at Lake Powell in 2012. They are particularly prevalent toward the southern area of the lake, where seasonally low water levels are now exposing mussel-encrusted shoreline (NPS 2016). Quagga mussel shells eventually wash up on beaches and can cut through skin, clothing, and pet paws.

Ecotourism in Glen Canyon

Declining water levels have exposed approximately 100,000 acres of Glen Canyon that were previously inundated by Lake Powell, creating new ecotourism opportunities to view landscapes and archaeological sites that have been underwater since the late 1960s (Baker 2022; Kolbert 2021). These include arches, side canyons, other rock formations, and lush desert ecosystems. This has created new hiking and sightseeing opportunities for GCNRA visitors since the publication of the 2007 FEIS.

Glen Canyon Dam to Lake Mead

The 15.5-mile river reach downstream of Glen Canyon Dam to Lees Ferry is managed by GCNRA staff; it is used by anglers, campers, commercial float trip operators, kayakers, and other boaters. Fishing opportunities for rainbow and brown trout also occur downstream of this reach.

The NPS manages most of the reach, except where it is bordered on the east by the Navajo Indian Reservation and on the south by the Hualapai Indian Reservation. GCNP staff regulates visitor use of the Colorado River downstream of Lees Ferry in accordance with the Colorado River Management Plan (NPS 2006).

Grand Canyon National Park begins downstream of the Lees Ferry boat ramp at the confluence of the Colorado and Paria Rivers. Designated a United Nations Educational, Scientific and Cultural Organization (UNESCO) World Heritage Site in 1979, Grand Canyon National Park is valued for its superlative natural and cultural resources, as well as its varied recreational experiences. Approximately 94 percent of GCNP (1,143,918 acres) qualifies as wilderness, as described in the 1964 Wilderness Act (Public Law 88-577) and NPS Management Policies 2006 (NPS 2006). This includes 10,919 acres of potential wilderness along the Colorado River corridor.

The Colorado River corridor borders Tribal lands for nearly half the distance from the put-in at Lees Ferry to the last take-out at Pearce Ferry. The Navajo Indian Reservation borders Grand Canyon National Park along the eastern bank of the Colorado River from near Lees Ferry to the confluence with the Little Colorado River at river mile (RM) 61.8. The Hualapai Indian Reservation borders the river corridor for approximately 108 miles from upstream of National Canyon (RM 167) to approximately RM 274. The Hualapai Indian Reservation offers camping, fishing, hiking, and big game hunting. A Tribal enterprise operates a river rafting company that offers rafting trips on the section of the Colorado River from Diamond Creek to Quartermaster Canyon. The NPS coordinates with Tribal neighbors to address resource management and visitor use concerns along shared boundaries. Access permits from the Navajo Nation, Havasupai Tribe, or Hualapai Tribe are required by each respective Tribe to access and recreate on Tribal lands.

GCNP receives 4 to 6 million visitors each year (NPS 2023e). **Table 3-38** summarizes visitation to GCNP for the most recent 6 years.

Table 3-38
Grand Canyon National Park Recreational Visitors

Year	Recreational Visitors
2017	6,254,238
2018	6,380,495
2019	5,974,411
2020	2,897,098*
2021	4,532,677
2022	4,732,101

Source: NPS 2023e
*Park closure April–May due to the COVID-19 pandemic

Table 3-39 summarizes the total number of visits to GCNP by visitor segment for 2022, the most recent year for which data are available.

Table 3-39
GCNP Visits by Visitor Segment for 2022

Recreation Visitors	Non-Recreation Visitors*	Concession Lodging	Tent Campers	RV Campers	Concession Camping	Backcountry Camping	Misc. Campers	Total Overnight Stays
4,732,101	7,720	526,467	89,825	56,759	39,400	331,623	14,141	1,058,215

Source: NPS 2023f
*The NPS defines reportable non-recreation visits to include:

- Persons going to and from inholdings across significant parts of park land
- Commuter and other through traffic using NPS-administered roads or waterways through a park for their convenience
- Tradespeople with business in the park
- Any civilian activity that is a part of or incidental to the pursuit of a gainful occupation (for example, guides)
- Government personnel (other than NPS employees) with business in the park
- Citizens using NPS buildings for civic or local government business, or attending public hearings
- Outside research activities (visits and overnights), if they are independent of NPS-legislated interests (for example, meteorological research) (NPS 2022a)

The Lees Ferry to Diamond Creek reach has relatively low-use densities and levels of development that provide opportunities for solitude on the Colorado River as well as at many camps and attraction sites. This section of the Colorado River is where the majority of whitewater boating occurs. Take-outs are at Diamond Creek and Pearce Ferry. The reach downstream of Diamond Creek offers different recreation opportunities than the river reach upstream as it transitions to a more populated and developed setting. Whitewater boating trips become intermingled with very high levels of general boating and recreation use in the Quartermaster Area. **Section 3.16** describes the social and economic importance of whitewater boating in the Grand Canyon.

Several helicopter operations transport people into the Grand Canyon and connect them with motorized pontoon boats that give 20-minute tours of the immediate area. These same helicopters provide a dual service in flying out boaters who have traveled from Diamond Creek on commercial motor day trips.

Camping also occurs in GCNP on undeveloped beaches along the river. The important variable is the number and quality of high-water versus low-water campsites.

Boating Facilities

No boating facilities are within GCNP. Development along the Colorado River within the park is limited to the utilitarian development at Phantom Ranch (RM 88) and Pipe Creek (RM 89.5). Other focal points include the launch ramp at Lees Ferry (within GCNRA), the helipad near Whitmore Wash (RM 187) on the Hualapai Reservation, the road access and minor structures operated by the Hualapai Tribe at Diamond Creek (RM 226), and the tourist area near Quartermaster Canyon (RM 260).

Camping between Glen Canyon Dam and Lake Mead occurs in GCNP on undeveloped beaches (sandbars) along the Colorado River. At a given time, the number and usability of campsites vary from year to year based on the magnitude of releases from Glen Canyon Dam and local topography. Additional factors include vegetation changes; erosion from tributary flooding, wind, and recreation use; and the closure of sites to protect sensitive resources (NPS 2006)

The average annual release volume was 9.1 maf from 2007 to 2019 and 8.1 maf from 2020 to 2022. The recent years of low release volumes have allowed accumulation of sand on the riverbed; however, that sand has not been redistributed to camping beaches because high flows have not occurred since 2018. From 2012 to 2018, there were more frequent HFEs, which build more sandbars and beaches, on average, in Marble and Grand Canyons. Since 2018, the lack of HFEs has resulted in greater erosion than deposition on the high-elevation sandbars, due to erosive flows in the main channel and gullying from side channels with no rebuilding. Also, the lack of HFEs has contributed to more vegetation encroachment since 2018 (USGS 2023d).

Of the 276 campsites referenced in Section 3.12.1.1 of the 2007 FEIS, 195 sites are still classified as "camps"; 68 sites have been classified as "non-camps" due to sand erosion, vegetation overgrowth, or both; 2 sites could not be ascertained based on the float-by methodology used during the November 2022 NPS Colorado River Management Plan (CRMP) monitoring trip; and 10 campsites were not evaluated (Kearsley 2023).

Lake Mead and Hoover Dam

LMNRA contains 1.5 million acres. It encompasses the 110-mile-long Lake Mead, 67-mile-long Lake Mohave, the surrounding desert, and the isolated Shivwits Plateau in Arizona. Recreation such as camping, boating, fishing, and hiking occurs on upper Lake Mead. The Overton Wildlife Management Area provides opportunities for wildlife viewing and photography, waterfowl and upland game bird hunting, hiking, and fishing. The Overton Wildlife Management Area has an average of 4,226 annual visitor use days.[18]

LMNRA extends along the lower Colorado River from the western border of Grand Canyon National Park to Davis Dam. Primary recreational activities on Lake Mead include cruising/sailing, personal watercraft usage, waterskiing, fishing, swimming, and diving. A number of campgrounds and picnic areas, including Boulder Beach, Calville Bay, Echo Beach, Las Vegas Bay, and Temple Bar, provide additional recreational opportunities. The number of visitors to LMNRA amounted to approximately 5.6 million visitors in 2022 (NPS 2023g).

Table 3-40 summarizes recreational visits to LMNRA for the last 6 years.

Table 3-40
Lake Mead National Recreation Area Recreational Visitors

Year	Recreational Visitors
2017	7,882,339
2018	7,578,958
2019	7,499,049
2020	8,016,510
2021	7,603,474
2022	5,578,226

Source: NPS 2023g

Table 3-41 summarizes the total number of visits to LMNRA by visitor segment for 2022, the most recent year for which data are available.

Table 3-41
Lake Mead National Recreation Area Visits by Visitor Segment for 2022

Recreation Visitors	Non-Recreation Visitors*	Concession Lodging	Tent Campers	RV Campers	Concession Camping	Backcountry Camping	Misc. Campers	Total Overnight Stays
5,578,226	202,320	28,256	43,138	54,901	226,803	28,747	48,949	430,793

Source: NPS 2023h

*The NPS defines reportable non-recreation visits to include:

- Persons going to and from inholdings across significant parts of park land

[18] Personal communication with the Nevada Department of Wildlife 2023

- Commuter and other through traffic using NPS-administered roads or waterways through a park for their convenience
- Tradespeople with business in the park
- Any civilian activity that is a part of or incidental to the pursuit of a gainful occupation (for example, guides)
- Government personnel (other than NPS employees) with business in the park
- Citizens using NPS buildings for civic or local government business, or attending public hearings
- Outside research activities (visits and overnights), if they are independent of NPS-legislated interests (for example, meteorological research) (NPS 2022a)

Water quality concerns are increasing, and are described in detail in **Section 3.8**. In the spring and summer of 2015, both Lake Mead and Lake Mohave experienced notable concentrations of harmful blue-green algae, which triggered harmful algal bloom advisories for various locations across the lakes (NPS 2023i). In 2022, a swimmer was fatally infected with a brain-eating amoeba at Lake Mead. Brain-eating amoebas are commonly found in bodies of warm freshwater, such as lakes, rivers, and geothermal water (NPS 2022b). These trends may continue to increase as water temperatures warm.

Declining reservoir elevations at Lake Mead in recent years have exposed mudflats along several areas of the shoreline. These have created dangerous conditions where recreationists have periodically become stuck in wet, muddy deposits. Some of these areas have access roads that previously enabled visitors to drive close to the shoreline when reservoir elevations were higher. As reservoir elevations have declined over recent years, visitors have often attempted to chase the shoreline both in their vehicles and by foot to gain access to the changing shoreline for such purposes as fishing, hiking, and other recreational activities. In doing so, they and their vehicles have become stuck in these muddy conditions, requiring assistance from NPS personnel and others to extract themselves and/or their vehicles.

Boating Facilities

LMNRA is considered one of the premier water-based recreation areas in the Nation. Most visitors participate in water-based recreational activities, primarily between May and September. These recreational activities are supported by marina and launch ramp facilities developed along the Lake Mead shoreline. On average, the majority of boats are personal watercraft. (Section 3.12.1.3 of the 2007 FEIS provides additional information on boating and shoreline public use facilities at LMNRA; the information is incorporated by reference.) **Table 3-42** shows critical elevations identified by the NPS for Lake Mead, below which marinas, boat docks, or boat launch ramps become inoperable.

Table 3-42
Critical Elevations for Lake Mead by Boating Facility

Lake Elevation (feet)	Impact and Facility
1,221	Full pool
1,150	Las Vegas Bay and Government Wash public launch ramps closed
1,125	Overton Beach Marina, Calville Ramp, and South Cove Ramp closed
1,112	Lake Mead Marina – Relocation of “C Dock” to Hemenway
1,110	Overton public launch ramps closed

Lake Elevation (feet)	Impact and Facility
1,100	Lake Mead Marina must relocate out of the protected harbor
1,080	Lake Mead Marina public launch ramp closed; Hemenway public launch ramp closed; Temple Bar public launch ramp closed
1,050	Echo Bay public launch ramp closed

Source: Henderson 2006

Since the publication of the 2007 FEIS, the Echo Bay, Boulder Harbor, and South Cove boat ramps have closed due to low water levels. The NPS facilities at the Temple Bar Marina are also inoperable; however, the concessionaire launch operations remain operable. The Pearce Bay launch ramp, a take-out point for rafts and whitewater boats, previously closed at elevation 1,175 feet. Access to Lake Mead was closed at Pearce Ferry in 2001 when the water elevation dropped to 1,175 feet. In 2010, the NPS extended Pearce Ferry Road 2 miles to the Colorado River to provide for river take-out operations for private and commercial river runners (NPS 2010).

Changes to water levels affect the usability of the remaining boat launch ramps throughout the year, especially in warmer months. Launch ramp closures resulting from declining water levels have resulted in longer lines, limited parking, and congestion at boat ramps and docks. In addition, ongoing maintenance and construction at ramps have resulted in temporary closures.

Hoover Dam to Davis Dam

Recreational opportunities available at Lake Mohave include boating, canoeing on northern parts of the lake, camping, exploring, fishing, photography, picnicking, swimming, parasailing, cliff diving (two locations), and water skiing. There are also hundreds of beaches that can only be accessed by boat. (The main shoreline access points and facilities for public use and boat launching for Lake Mohave are described in Section 3.12.1.4 in the 2007 FEIS; this information is incorporated by reference.)

Davis Dam to Parker Dam

The Davis Dam to Parker Dam reach includes several recreational areas along the Colorado River, including Laughlin, Bullhead City, Davis Camp, Needles, Havasu National Wildlife Refuge (NWR), Lake Havasu State Park, and Bill Williams River NWR. (Relevant recreational areas are briefly described in Section 3.12.1.5 in the 2007 FEIS; the information is incorporated by reference.) Lake Havasu is the premier attraction area within the Davis Dam to Parker Dam reach. **Table 3-43** lists the visitation at Arizona's Lake Havasu and Cattail Cove State Parks.

Table 3-43
Visitation at Arizona's Lake Havasu and Cattail Cove State Parks

Year	Lake Havasu State Park Visitation	Cattail Cove State Park Visitation
2016	477,283	70,442
2017	519,704	106,545
2018	551,203	111,376
2019	488,597	111,262
2020	598,403	116,822

Year	Lake Havasu State Park Visitation	Cattail Cove State Park Visitation
2021	492,074	95,179

Source: Northern Arizona University 2022a, 2022b

Parker Dam to Cibola Gage

The Parker Dam to Cibola Gage reach includes several recreational areas, including Parker Strip Recreation Area, Palo Verde Diversion Dam, Blythe, and Cibola NWR. (Relevant recreational areas are briefly described in Section 3.12.1.6 in the 2007 FEIS; this information is incorporated by reference.)

Cibola Gage to Imperial Dam

The Cibola Gage to Imperial Dam reach includes a few recreational areas: Picacho State Recreation Area, Imperial NWR, and Martinez Lake. (Relevant recreational areas are briefly described in Section 3.12.1.7 in the 2007 FEIS; this information is incorporated by reference.)

Imperial Dam to NIB

The Imperial Dam to the NIB reach includes a few recreational areas along the Colorado River, including Betty's Kitchen and Mittry Lake Wildlife Area. (Relevant recreational areas are briefly described in Section 3.12.1.8 in the 2007 FEIS; the information is incorporated by reference.)

NIB to SIB

The NIB to the SIB reach includes shoreline public use facilities in the city of Yuma, Arizona. Located on the edge of the historical floodplain to the east of the Colorado River, typical water activities within this reach include boating, swimming, and sport fishing.

Reservoir Boating

Reservoir boating is affected by fluctuating reservoir elevations; these fluctuations specifically cause changes in exposure to boating navigation hazards and changes in safe boating capacities. Hazards such as exposed rocks may become more evident, and changes in navigation patterns may be necessary as reservoir elevations decline. At low-pool elevations, special buoys or markers may be placed within reservoirs to warn boaters of navigation hazards. In addition, signs may be placed in areas that are deemed unsuitable for navigation.

Lake Powell

The navigation system on Lake Powell utilizes regulatory buoys and other marking devices to warn boat operators of hazardous conditions associated with subsurface obstructions or changes in subsurface conditions that could be hazardous for safe passage. Section 3.12.2.1 of the 2007 FEIS describes safe boating navigation and safe boating capacity on Lake Powell; the information is incorporated by reference. Placement of many of these marking devices depends on the lake elevation. Recreational boating is the most frequent type of boating activity on Lake Powell. One of the most popular activities at Lake Powell is to take out houseboats and motorboats for multiple day excursions to explore the reservoir. As the pool elevation decreases, the surface area suitable for boats also decreases. Since the pool elevation has decreased since the publication of the 2007 FEIS, the safe boating capacity at Lake Powell has subsequently decreased.

As of 2016, thousands of adult quagga mussels have been found at Lake Powell attached to canyon walls, Glen Canyon Dam, boats, and other underwater structures. Quaggas rapidly multiply, are easy to spread, and encrust and clog boat engines, shorelines, and anywhere else conducive to their growth. These impacts are particularly prevalent in the southern portions of the reservoir. Adult mussel populations are expected to expand and increase over the next few years (NPS 2023i).

Lake Mead

Regulatory buoys and other marking devices are used on Lake Mead to warn boat operators of dangers, obstructions, and changes in subsurface conditions in the main channel or side channels. (Section 3.12.2.2 of the 2007 FEIS describes safe boating navigation and safe boating capacity on Lake Mead; this information is incorporated by reference.) Since the publication of the 2007 FEIS, the NPS has extended the Pearce Ferry launch ramp to provide river take-out operations for private and commercial river runners. However, due to the close proximity of the developing Pearce Ferry Rapid, the public launch of boats is prohibited (NPS 2010). Since the pool elevation has decreased since the publication of the 2007 FEIS, the safe boating capacity at Lake Mead has subsequently decreased.

Lake Mohave and Lake Havasu

Because Lake Mohave and Lake Havasu will continue to be operated to meet monthly target elevations, reservoir boating safe navigation and capacity in these reaches will not be impacted by the proposed alternatives.

River and Whitewater Boating

Whitewater boating is the key recreational activity in the Grand Canyon from Lees Ferry to the Diamond Creek or Pearce Ferry take-outs. Other reaches are not predominantly whitewater localities; therefore, they will not be discussed in this section.

Glen Canyon Dam to Lake Mead

Grand Canyon river trips launch at Lees Ferry in GCNRA and take out at Diamond Creek on the Hualapai Indian Reservation or at Pearce Ferry in LMNRA. River trips are conducted using a variety of types and sizes of boats and rafts; group sizes can range up to 32 people (including guides). Trip lengths range up to 25 days and can be run by commercial companies or by private individuals. There are various means of joining trips, including launching from Lees Ferry, hiking into or out of the canyon to join and leave a trip, and limited access by vehicle and helicopter (commercial use only) to join trips in the western portion of the Grand Canyon.

GCNP staff regulates recreational boating in accordance with the CRMP (NPS 2006). The CRMP prescribes management of recreational use by establishing limits on the number of daily launches, group size, trip length, and motorized and nonmotorized use periods. In general, whitewater navigability can be affected by lower flows and by large amounts of side canyon debris that gets washed into the river channel. Because of this and reduced water levels, Separation Rapid is now visible, and it is consequentially more difficult to navigate. As Lake Mead has receded, the Colorado River has scoured a new channel in the silts deposited by the waters of Lake Mead. While most of the river still follows the old river channel, a new channel has developed near Pearce Ferry, creating a new impassible (going upstream) class VI rapid known as the Pearce Ferry Rapid (Joel 2016).

Intermittent, larger-volume and higher-magnitude flows could improve navigability at some of these rapids.

Hoover Dam to SIB

The proposed alternatives are not expected to adversely affect river and whitewater boating between Hoover Dam and the SIB.

Sport Fishing

There are no specific reservoir elevation thresholds or river stages related to sport fishing identified from the literature reviewed. Catch rates for reservoir fishing are assumed to be directly related to reservoir habitat. Fishing satisfaction is assumed to be directly related to 1) the general recreation issues of boating access to water via shoreline facilities, and 2) the boating navigation potential for hazards or reservoir detours due to low reservoir elevations.

Lake Powell and Glen Canyon Dam

Lake Powell supports a popular warmwater sport fishery comprised mainly of striped and smallmouth bass. The striped bass depend on threadfin shad for a significant portion of their diet. The threadfin shad in Lake Powell are at the northernmost portion of their range, and they are sensitive to fluctuations in water temperature. Gizzard shad may become an important striped bass forage fish. In addition to striped and smallmouth bass, Lake Powell supports largemouth bass, walleye, channel catfish, bluegill, and black crappie. Angler use in 2018 was at a 40-year low, mainly attributed to a decline in the percentage of boat days that were spent angling (Blommer and Gustaveson 2021).

Glen Canyon Dam to Lake Mead

The 15.5-mile Glen Canyon reach of the Colorado River supports a Blue Ribbon recreational rainbow trout fishery that attracts local, national, and international anglers. The NPS, in coordination with the Arizona Game and Fish Department and the Service, manages fish in all waters within the GCNRA and GCNP. The intention of Blue Ribbon management is to provide a quality fishing opportunity where anglers can catch larger-than-average trout, at a relatively high catch rate, in a unique recreational setting. Most angling is done from boats or is facilitated by boat access, often provided by guide services. Some anglers also fish by wading, or they fish from shore.

Fishing in the Glen Canyon reach occurs year-round. Peak usage is in April and May; however, substantial fishing has occurred from March through October in most years (Rogowski and Boyer 2020). An estimated total of 7,654 anglers used the rainbow trout fishery in 2019; of these, 5,469 were boat anglers and 2,185 were walk-in anglers (Rogowski and Boyer 2020).

Section 3.13.1 provides further information on rainbow trout dynamics in the Glen Canyon reach.

Lake Mead and Hoover Dam

Lake Mead has an excellent warmwater sport fishery comprised of largemouth bass, striped bass, channel catfish, rainbow trout, bullhead catfish, sunfish, crappie, and bluegill. The majority of the catch consists of striped bass. Fishing is generally better in the fall months of September, October, and November. Larger fish are caught by deepwater trolling in spring from March through May.

The Lake Mead Fish Hatchery, operated by the Nevada Department of Wildlife (NDOW), historically raised rainbow trout, endangered razorback suckers, and bonytail chub. Since the publication of the 2007 FEIS, the Lake Mead Fish Hatchery ceased operations in 2022 in response to Lake Mead declining below 1,060 feet, the point below where the hatchery drew its water (Peterson 2022). The NDOW and SNWA are currently developing a project to replace the hatchery's water supply line to draw deeper in the water column.

Hoover Dam to Davis Dam
Lake Mohave's fishery is similar to Lake Mead's fishery. In Lake Mohave, there are largemouth bass, striped bass, channel catfish, rainbow trout, bullhead catfish, sunfish, crappie, and bluegill. Largemouth and striped bass are in deep water in the winter and move into shallow water to spawn in the spring. Fishing is open year-round, but the best fishing generally occurs in September, October, and November. For deepwater trolling, March through May tends to provide the best conditions.

Davis Dam to Parker Dam
Striped bass is the dominant sport fish in Lake Havasu. They can be caught throughout the year, but the best fishing locations change with the seasons and with water temperature. The largemouth bass population supports tournaments nearly every weekend from September through May. The smallmouth bass population has experienced an increase in numbers over the past couple of years by adding a needed resource for tournament anglers. Channel catfish are abundant and average 2 to 4 pounds in size. Flathead catfish grow to large sizes in Lake Havasu. Only a limited number of anglers fish specifically for catfish. Black crappie numbers are limited due to overharvesting and a lack of habitat.

Parker Dam to SIB
Fishing in Cibola NWR is limited to certain times of the year. Cibola NWR is managed to protect wintering waterfowl that use Cibola Lake. The lake is closed to fishing from Labor Day to March 15. Sport fishing in Cibola Lake includes largemouth, smallmouth, and striped bass; channel and flathead catfish; crappie; sunfish; tilapia; and common carp.

The Imperial NWR is managed as a refuge and breeding area for migratory birds and other wildlife. Hunting and fishing are permitted in some areas, according to state regulations, and fishing by boat is allowed in the mainstream Colorado River any time of the year.

3.14.2 Environmental Consequences

Methodology

This section examines the potential effects of the alternatives, including the No Action Alternative, on recreation within the analysis area. Reclamation's CRMMS modeling results helped develop potential releases, reservoir elevations, and flow rates from the action alternatives. The results of these analyses are used throughout this section.

Method Used to Assess Shoreline Public Use Facilities

This section analyzes the impacts that reservoir elevations decreasing below critical thresholds would have for use of selected marinas, boat docks, and launch ramps, as well as whether impacts could occur in access to or use of attraction features. (Threshold reservoir elevations were determined using the methodology in the 2007 FEIS.) The threshold elevations were used as indicators of recreational facilities that might be rendered inoperable or that might require relocation or modification to maintain their operation. **Figure 3-5** provides the projections of reservoir elevations for 2024, 2025, and 2026 (the end of the interim period). The narrative of the alternatives' effects is provided below for selected facilities at both Lake Powell and Lake Mead. These facilities are representative of the alternatives' potential effects on shoreline recreation opportunities at each reservoir.

Method Used to Assess Reservoir Boating and Navigation Hazards

This analysis assesses the impacts of reservoir elevations decreasing below critical thresholds, which would result in boating navigation hazards and changing navigable areas and passageways. It also assesses whether corresponding decreases in reservoir surface areas might affect safe boating capacities. (Threshold pool elevations were determined using the methodology identified in the 2007 FEIS.)

Method Used to Assess Whitewater Boating

This analysis uses river flow data from **Section 3.6** to analyze whether there would be increased exposures to boating navigation hazards, changes in access or use of rest areas and take-outs, or changes in trip durations resulting under the action alternatives, as compared with the No Action Alternative. (Threshold river flows were determined using the methodology identified in the 2007 FEIS.) Whitewater boating is the key recreational activity in the Grand Canyon downstream of Lees Ferry and upstream of Lake Mead. The 2007FEIS analysis also includes a discussion of areas on the Colorado River that could become unsafe for whitewater boating at certain flows due to hazards such as exposed rocks, changes in navigation patterns caused by obstructions, and increased or decreased flow velocities. These flows were also analyzed to determine elevations at or below which various whitewater boating facilities (rest areas and take-out points) might be rendered inoperable or require modification to maintain their operation.

Method Used to Assess Sport Fishing

This analysis evaluates changes in sport fishing opportunities by river reach under the action alternatives as compared with the No Action Alternative. The assessment of sport fishing was based on a literature review to determine the current status of fish assemblages in the analysis area. No specific reservoir elevation thresholds related to sport fishing were found. A general discussion about changes in flow and salinity and possible effects on sport fish is also provided.

A more detailed analysis of effects on rainbow trout based on changes in water temperature is used for the Colorado River reach between Glen Canyon Dam and Lake Mead. Water temperature changes may affect sport fish. Rainbow trout were chosen for the analysis based on the importance of their recreational fishery in the Colorado River reach below Glen Canyon Dam.

Striped bass and threadfin shad in Lake Powell and Lake Mead were selected to represent the reservoir sport fishery; striped bass are a sport fish, and threadfin shad are their food source.

Assumptions

In addition to being consistent with the modeling assumptions, this analysis assumes that recreation in the impact analysis area will increase over time, provided dead pool is not reached.

Impact Indicators

- Threshold reservoir elevations
- Threshold river flows
- Water temperatures
- Rainbow trout water temperature thresholds
- Striped bass and threadfin shad

Issue 1: How would reduced reservoir levels impact recreation at Lake Powell?

Section 3.14.1, **Table 3-37** identifies the threshold elevations below which shoreline recreational facilities at Lake Powell could be affected**.** Below these elevations, facility adjustments or capital improvements would be required, creating potential impacts on recreation at Lake Powell.

Summary

Under all alternatives, projected Lake Powell elevations for much of the analysis period are below the critical thresholds for most boat launch facilities and safely navigating Castle Rock and Gregory Butte. This would result in a reduction in the quality of or loss of reservoir boating opportunities on Lake Powell. Under all alternatives, dock access would continue to be unavailable from the Rainbow Bridge National Monument shoreline, which would continue until the NPS could secure funding to develop a long-term access solution.

Under all alternatives, impacts on public health resulting from harmful algal blooms would likely increase as lake elevations decline. Under all alternatives, declining pool elevations would expose additional areas of Glen Canyon that were previously inundated by Lake Powell. This would continue to create new visitation patterns and resource protection challenges given access to new areas, as described in the affected environment. There may also be new recreation and ecotourism positive benefits in some locations. All alternatives are not expected to significantly impact sport fish populations. Recreation impacts at Lake Powell would be slightly reduced under the action alternatives because the action alternatives preserve more water in Lake Powell and reduce overall variability in water surface elevations.

No Action Alternative

Boat Launch Facilities

Under the No Action Alternative, the median 2024 projected Lake Powell elevation (3,510 feet) is below the critical threshold for all Lake Powell boat launch facilities, which would necessitate they be closed or relocated. As described in **Section 3.14.1**, launch ramp closures resulting from declining water levels would continue to result in longer lines, limited parking, and congestion at boat ramps and docks. If the median 2024 projected Lake Powell elevation were to be reached before the NPS develops the Stanton Creek area launch ramp, then Lake Powell would be unable to provide reservoir boating opportunities. The ability for boat launch access to continue under the No Action Alternative would depend on how quickly the NPS would be able to secure funding/permitting for and construct new boat launch facilities in a riverine environment.

Safe Boating Capacities and Exposure to Navigation Hazards

In general, as reservoir elevations drop, hazards such as submerged snags and boulders can become exposed or become closer to the surface, increasing the likelihood that boats can come in contact with such hazards. The elevations of such hazards are often unknown until the hazards become exposed. At a Lake Powell elevation of 3,620 feet, hazardous obstructions result in the NPS prohibiting boating around Castle Rock and Gregory Butte. Under the No Action Alternative, the median 2024 projected Lake Powell elevation is below this threshold, which would result in the NPS implementing boating restrictions around Castle Rock and Gregory Butte. These restrictions would likely be in place throughout the analysis period, unless the upper projected pool elevation for 2026 were reached.

Access or Use of Rainbow Bridge

Under the No Action Alternative, dock access would continue to be unavailable from the Rainbow Bridge National Monument shoreline. Access would continue to be limited to the Rainbow Bridge Trail. Boat and small vessel shoreline access would likely become more difficult to impossible as pool elevations decrease. These impacts would continue until the NPS could secure funding to develop a long-term access solution.

Harmful Algal Blooms

Under the No Action Alternative, reduced pool elevations would result in increasingly warm water temperatures, which could create conditions that would be more conducive to the growth of harmful algal blooms. Harmful algal blooms may increasingly pose serious health risks to humans and animals. (Water quality concerns are described in detail in **Section 3.8**.)

Ecotourism in Glen Canyon

Under the No Action Alternative, declining pool elevations would expose additional areas of Glen Canyon that were previously inundated by Lake Powell. This would continue to create new ecotourism opportunities to view landscapes and archaeological sites, as described in the affected environment.

Lake Powell Sport Fish Populations

Under the No Action Alternative, the maximum lethal limits of 37 and 33°C for threadfin shad and striped bass, respectively, would not be exceeded. These water temperatures are for the upper 10 feet of the reservoir, and lower depths provide cooler water. Reclamation assumes that striped bass and threadfin shad would be able to move into the cooler thermocline during the summer months. Under the No Action Alternative, water temperatures would not drop below the lower lethal limit of 5°C for striped bass or threadfin shad. Because surface temperatures would not exceed the lethal tolerances of either species, and it is assumed that both species would have adequate thermal refugia, substantial temperature-related impacts on the reservoir sport fishery are not anticipated to occur under the No Action Alternative.

Action Alternative 1

In general, impacts on recreation under Action Alternative 1 would be similar to those described under the No Action Alternative. Impacts on recreation under Action Alternative 1 that differ from the No Action Alternative are presented below.

Boat Launch Facilities

Under Action Alternative 1, the median 2024 projected Lake Powell elevation (3,510 feet) is below the critical threshold for all Lake Powell boat launch facilities, which would result in impacts similar to those described under the No Action Alternative. The highest projected 2024 pool elevations under Action Alternative 1 (3,560 feet) are higher than under the No Action Alternative, which increases the likelihood that the Wahweap Marina, Antelope Point Marina, Bullfrog Marina, and Halls Crossing Marina would remain operable. This would slightly reduce the impacts on boat launch facilities under Action Alternative 1, as compared with the No Action Alternative.

Action Alternative 2

Overall, Action Alternative 2 would improve the median pool elevation conditions over time by preserving more water in Lake Powell and reducing the overall variability in water surface elevations, compared with the No Action Alternative; this would be similar to Action Alternative 1. In general, under Action Alternative 2, impacts on recreation at Lake Powell would be similar to those described under Action Alternative 1.

Cumulative Effects

The Glen Canyon Dam/Smallmouth Bass flow options would not cumulatively affect recreation on Lake Powell.

Issue 2: How would reduced flows downstream of Lake Powell affect recreation from Glen Canyon Dam to Lake Mead?

Summary

Under all alternatives, daytime flows would not drop lower than the safe whitewater boating threshold of 5,000 cfs. Therefore, there would be no change in exposure to unsafe boating conditions caused by changes in river levels. Under all alternatives, lethal limits for rainbow trout are not projected to be exceeded in any month throughout the analysis period. As seen in **Figure 3-31**, the warmest release temperatures were observed in trace 1999 80 percent under the action alternatives. As seen in **Figure 3-32**, release temperatures were also more likely to exceed 20°C under the action alternatives, which could result in a greater likelihood that temperatures would reach or exceed the 23°C threshold at which rainbow trout stop growing from 2023 to 2026. This would negatively impact the rainbow trout fishery in the Glen Canyon reach. However, under the No Action Alternative, Lake Powell would be much more likely to reach dead pool (3,370 feet). If Lake Powell were to reach dead pool, it would lead to a large increase in water temperature, which would lead to potentially lethal conditions for rainbow trout.

No Action Alternative

Boating

Current operation of Glen Canyon Dam under the 2007 Interim Guidelines requires a minimum flow release of 8,000 cfs between 7:00 a.m. and 7:00 p.m. and 5,000 cfs at night. Therefore, under the No Action Alternative, daytime flows would not drop lower than the safe whitewater boating threshold of 5,000 cfs. Releases from Glen Canyon Dam would generally be higher than these minimum flows. Therefore, there would be no change in exposure to unsafe boating conditions caused by changes in river levels. Minor changes in exposure to boating navigation hazards caused by a change in river velocity, changes in access or use of rest areas and take-out points, changes in trip duration caused by changes in river velocity, or changes in the ability to use sport fishing sites caused by a change in flows may occur under the No Action Alternative. These changes would not be substantial, and they would not significantly affect recreational boating use or opportunities.

However, under the No Action Alternative, Lake Powell would be much more likely to reach power pool (3,490 feet). If Lake Powell were to reach power pool, it would likely result in lower, unknown releases that could have the potential to create unsafe whitewater boating conditions in the Grand Canyon.

Releases from Glen Canyon Dam throughout the analysis period have the potential to be below the threshold to produce HFEs, which would result in reduced sandbar building. In the long term, this would negatively impact the availability of campsites for boaters in the Grand Canyon. See **Section 3.8.2** for further details on the impacts on sandbar building.

As analyzed in the LTEMP EIS and ROD, a slight increase (2 percent) in suspended sediment would occur at Hualapai recreational facilities in the western Grand Canyon when HFEs are implemented (DOI 2016). The probability of triggering HFEs under the alternatives is described in **Section 3.8.2**, under Issue 3. Reclamation would address any concerns related to these facilities in the manner stated in the 2012 letter between Reclamation and the Hualapai Tribe (Walkoviak 2012; DOI 2016).

Sport Fish Populations

Water temperatures above 21°C have the highest potential to affect spawning, incubation, growth, and mortality of rainbow trout. Temperatures 23°C and above have the potential to stop growth, and temperatures 25°C and above are known to be lethal (FAO 2023). Under the No Action Alternative, under trace 1999 90 percent ESP, water temperatures are projected to be the warmest (23°C) just before outflows at Glen Canyon Dam switch to the river outlet works in fall 2024 (**Figure 3-31**). Release temperatures are also projected to be high (23°C) in trace 1999 80 percent ESP when Lake Powell's pool elevation is projected to be just above the power pool in July 2023 and after elevations drop closer to the bypass elevation in July 2025 and in subsequent years (**Figure 3-31**). Growth of rainbow trout may be limited when temperatures reach 23°C. Under the No Action Alternative, lethal limits for rainbow trout are not projected to be exceeded in any month. However, under the No Action Alternative, Lake Powell would be much more likely to reach dead pool (3,370 feet). If Lake Powell were to reach dead pool, it would lead to a large increase in water temperature, which would lead to potentially lethal conditions for rainbow trout. See **Section 3.13.2** for further details on the impacts on fish species.

Action Alternative 1

Boating

Under Action Alternative 1, daytime flows would not drop lower than the safe whitewater boating threshold of 5,000 cfs. Therefore, impacts on whitewater boating would be similar to those described under the No Action Alternative (assuming power pool conditions are not reached under the No Action Alternative).

Sport Fish Populations

Under Action Alternative 1, both 1999 80 percent ESP and 1999 90 percent ESP traces are projected to have the warmest temperatures with releases exceeding 20°C in all years within the analysis period (**Figure 3-31**). Projected release temperatures under Action Alternative 1 would have higher temperatures than under the No Action Alternative (assuming dead pool is not reached under the No Action Alternative), resulting from Lake Powell elevations being held just above the power pool. Compared with the No Action Alternative, this could result in a greater likelihood that temperatures would reach or exceed the 23°C threshold at which rainbow trout stop growing. Under Action Alternative 1, lethal limits for rainbow trout are not projected to be exceeded in any month.

Action Alternative 2

Boating

The impacts on whitewater boating would be similar to those described under Action Alternative 1.

Sport Fish Populations

The impacts on the rainbow trout sport fishery would be similar to those described under Action Alternative 1.

Cumulative Effects

The Glen Canyon Dam Smallmouth Bass flow options would cumulatively impact the rainbow trout sport fishery within the Glen Canyon Dam to Lake Mead reach of the Colorado River due to changes in the water temperature released from Glen Canyon Dam. Reducing water temperatures to prevent smallmouth bass establishment would benefit rainbow trout by reducing water temperatures to a range conducive to rainbow trout, aerating the water, and limiting the potential for smallmouth bass establishment. Under all alternatives, the effects of this cumulative action would be beneficial to rainbow trout, unless water levels in Lake Powell reached minimum power pool levels. At this elevation, all flows passing through Glen Canyon Dam would be directed through the river outlet works out of necessity, nullifying this cumulative action.

If the Glen Canyon Dam Smallmouth Bass flow options were not implemented, the action alternatives may result in poorer outcomes for rainbow trout due to increased water temperatures, predation from smallmouth bass, increased entrainment of nonnative fish species, and lower dissolved oxygen when the dam would be operated near 3,500 feet. These dynamics are further described in **Section 3.13.2.**

Issue 3: How would reduced reservoir levels impact recreation at Lake Mead?

Section 3.14.1, **Table 3-42** identifies the threshold elevations below which shoreline recreational facilities at Lake Mead could be affected. Facility adjustments or capital improvements would be required below these elevations, creating potential impacts on recreation at Lake Mead.

Summary

Under the No Action Alternative, the highest median projected Lake Mead elevation is below the critical threshold for all Lake Mead boat launch facilities except the Pearce Ferry Road launch ramp. This would necessitate closing the boat launch facilities or relocating them throughout the entire analysis period. The slight rebound in Lake Mead pool elevations under the action alternatives could marginally help limit the closure or relocation of boat launch facilities at Lake Mead in year 2026, compared with the No Action Alternative. Additionally, under all alternatives, the projected median pool elevation for Lake Mead would be at a level at which boaters are likely to encounter boating navigational hazards. Under all alternatives, projected surface water temperatures at Lake Mead are not anticipated to impact sport fish.

No Action Alternative

Access or Use of Lake Mead Boating Facilities

Under the No Action Alternative, the highest median projected Lake Mead elevation (1,025 feet) is below the critical threshold for all Lake Mead boat launch facilities except the Pearce Ferry Road launch ramp. This would necessitate closing the boat launch facilities or relocating them throughout the entire analysis period. Launch ramp closures resulting from declining water levels would result in longer lines, limited parking, congestion at boat ramps and docks, and the potential loss of most facilities. Declining water levels would also likely continue to contribute to public safety concerns as recreationists attempt to navigate through exposed mudflats to access shoreline recreation opportunities, as described under **Section 3.14.1**.

Safe Boating and Navigation Hazards

Over the years, sediment has built up in the section of the reservoir between Grand Wash Cliffs and Pearce Ferry. When Lake Mead's elevation drops below 1,170 feet, there is no well-defined river channel in this upper portion of Lake Mead, making it dangerous for boaters (NPS 2006). In general, as reservoir elevations drop, hazards such as submerged snags and boulders can become exposed or become closer to the surface, increasing the likelihood that boats can come in contact with such hazards. The elevations of such hazards are often unknown until the hazards become exposed. Under the No Action Alternative, the projected median pool elevation for Lake Mead would be below 1,170 feet throughout the period of analysis, which would result in boaters encountering navigational hazards in upper Lake Mead.

Sport Fish Populations

The situation for striped bass and threadfin shad in Lake Powell is expected to be similar at Lake Mead. However, threadfin shad are near the northern limit of their range at Lake Powell. Threadfin shad are less likely to be affected by cold winter temperatures at Lake Mead.

Action Alternative 1

Access or Use of Lake Mead Boating Facilities

Under Action Alternative 1, the 2024 median projected Lake Mead elevation would be below the critical threshold for all Lake Mead boating facilities except for the Pearce Ferry Road launch ramp; therefore, the impacts on boating facilities would be similar to those described under the No Action Alternative for 2024. While the 2026 median pool elevation projection (1,015 feet) remains below the critical threshold for most Lake Mead boating facilities, the upper range of projections for 2026 could be up to 1,060 feet. This could enable the Echo Bay public launch ramp to reopen, unlike under the No Action Alternative. Overall, the slight rebound in Lake Mead pool elevations under Action Alternative 1 could marginally help limit the closure or relocation of boat launch facilities and public safety risks due to shoreline access at Lake Mead in year 2026 compared with the No Action Alternative.

Safe Boating and Navigation Hazards

Under Action Alternative 1, the projected median pool elevation for Lake Mead would be below 1,170 feet throughout the period of analysis, which would result in boating navigational hazards similar to those described under the No Action Alternative. These impacts could be slightly reduced in 2025 and 2026 due to the slightly higher Lake Mead pool elevations under Action Alternative 1, as compared with the No Action Alternative.

Sport Fish Populations

Impacts on sport fish populations would be similar to those described under the No Action Alternative.

Action Alternative 2

Under Action Alternative 2, impacts on Lake Mead boating facilities, safe boating and navigation hazards, shoreline access, and sport fish populations would be similar to those described under Action Alternative 1.

Cumulative Effects

The Glen Canyon Dam/Smallmouth Bass flow options would not cumulatively affect recreation at Lake Mead.

Issue 4: How would reduced flows downstream of Lake Powell affect recreation from Hoover Dam to SIB?

Summary

Under all alternatives, flow releases from Hoover Dam, Davis Dam, Parker Dam, and Imperial Dam would all be within the historical operating range. Therefore, there would be minimal changes in exposure to boating navigation hazards caused by changes in the river's elevation, changes in exposure to boating navigation hazards caused by changes in the river's velocity, changes in access or use of rest areas and take-out points, changes in trip duration caused by changes in the river's velocity, or decreases in access or use of sport fishing sites caused by changes in flows. The sport fishery in this reach is primarily in warm water. The minor changes in water temperatures that may occur downstream of Hoover Dam would not be expected to affect warmwater sport fish.

No Action Alternative

Under the No Action Alternative, flow releases from Hoover Dam, Davis Dam, Parker Dam, and Imperial Dam would all be within the historical operating range. Therefore, there would be minimal changes in exposure to boating navigation hazards caused by changes in the river's elevation, changes in exposure to boating navigation hazards caused by changes in the river's velocity, changes in access or use of rest areas and take-out points, changes in trip duration caused by changes in the river's velocity, or decreases in access or use of sport fishing sites caused by changes in flows. The sport fishery in this reach is primarily in warm water. The minor changes in water temperatures that may occur downstream of Hoover Dam would not be expected to affect warmwater sport fish.

Action Alternative 1

Under Action Alternative 1, impacts on recreation from Hoover Dam to SIB would be the same as those described under the No Action Alternative.

Action Alternative 2

Under Action Alternative 2, impacts on recreation from Hoover Dam to SIB would be the same as those described under the No Action Alternative.

Cumulative Effects

The Glen Canyon Dam/Smallmouth Bass flow options would not cumulatively affect recreation from Hoover Dam to SIB.

3.15 Electrical Power Resources

3.15.1 Affected Environment

This section provides an overview of electrical power (that is, hydropower) generation, power marketing, and the Colorado River Basin power funds used to manage electrical power revenues and expenditure requirements for mainstream Colorado River dams. The 2007 Interim Guidelines describe in detail the electrical power resources that occur within the Colorado River Basin and within the analysis area. This section analyzes the same resources as the 2007 Interim Guidelines and provides updated information, data, and conditions since the publication of the 2007 Interim Guidelines (Reclamation 2007). Electrical power resources analyzed include:

- Amount of electrical power generation and capacity
- Economic value of electrical power produced
- Electrical power-related contributions to the different Colorado River Basin power funds and programs supported by these funds

Overview

The primary power resources affected by the proposed alternatives include the Glen Canyon Powerplant, Hoover Powerplant, and Parker-Davis Project Powerplants. Other smaller facilities along the river include Headgate Rock Powerplant, Senator Wash, Siphon Drop, and Pilot Knob. Reclamation is responsible for the operation and maintenance of Glen Canyon, Hoover, Parker, and

Davis facilities. WAPA is responsible for marketing and transmitting the power across the Upper and Lower Basins (Reclamation 2007).

Hydropower Generation

Hydropower generation occurs when water stored in a reservoir passes through a turbine located on a generating unit. The amount of power generated is directly related to the amount of water passing through the turbines and the elevation of the reservoir. The depth of the reservoir controls the force, or head,[19] the water has when moving through the turbines. Hydropower generation has two main measurable components: energy, which is the amount of power generation that occurs over time and is measured in MWh, and capacity, which is the maximum amount of energy that can be produced instantaneously and is measured in megawatts (MW).

Energy is mainly impacted by the amount of water that passes through the generators and the depth of the reservoir. The higher the reservoir elevation, the more force, or head, the water can exert when passing through the turbines. Capacity is mainly impacted by the depth of the reservoir and the availability of generators. Additional information on power generation, control, regulation, reserves, and ramping can be found in 2007 FEIS Section 3.11.1.1; the information is incorporated by reference (Reclamation 2007).

There have been no changes to the manner in which hydropower is generated since 2007. However, regulations such as the LTEMP have led to changes in typical operations. In addition, recent drought conditions in the Basin have led to a substantial decrease in hydropower generation since the 2007 Interim Guidelines (Reclamation 2021b). Changes in hydropower generation are described in the powerplant-specific subsections below.

Power Marketing

WAPA markets and administers power contracts for electricity generated from Reclamation-owned and -operated hydropower facilities (that is, Glen Canyon, Hoover, Parker, Davis, and the smaller generation facilities). The BIA administers Headgate Rock Powerplant.

WAPA markets energy and capacity to its customers. Power marketing comes in two terms: 1) firm—or guaranteed to be available—capacity and energy; and 2) non-firm, which only includes charges for energy delivered. Firm and non-firm contracts can be short or long term. The majority of CRSP power is sold under long-term, firm contracts. Customers can purchase firm and non-firm power through contracts with individual hydropower facilities. Contracts for the Hoover Powerplant have been re-signed since the 2007 Interim Guidelines. Contracts for Parker-Davis Project were signed before the 2007 Interim Guidelines and terminate in 2028. It is expected new contracts will be signed to replace the expiring contract. The contract for Glen Canyon Dam terminates in 2024, and new contracts effective 2024 through 2057 have been executed with nearly identical terms and conditions (Reclamation 2021b).

[19] The pressure caused by a difference in water depth. In this case, it is the difference between the lake reservoir elevation and the hydroelectric generators.

Table 3-44 shows the total generation capability of each Western Electricity Coordinating Council (WECC) area. These WECC areas cover the entire Upper and Lower Colorado River Basins. Glen Canyon, Hoover, Parker, and Davis Powerplants account for approximately 2.2 percent of the total capacity.

Table 3-44
Generation Capability in WECC Areas

WECC Area	Available Capacity (MW)
Rocky Mountain Region	34,053.99
Southwest Region	45,483.61
California-Mexico Region	89,925.74

Source: WECC 2023

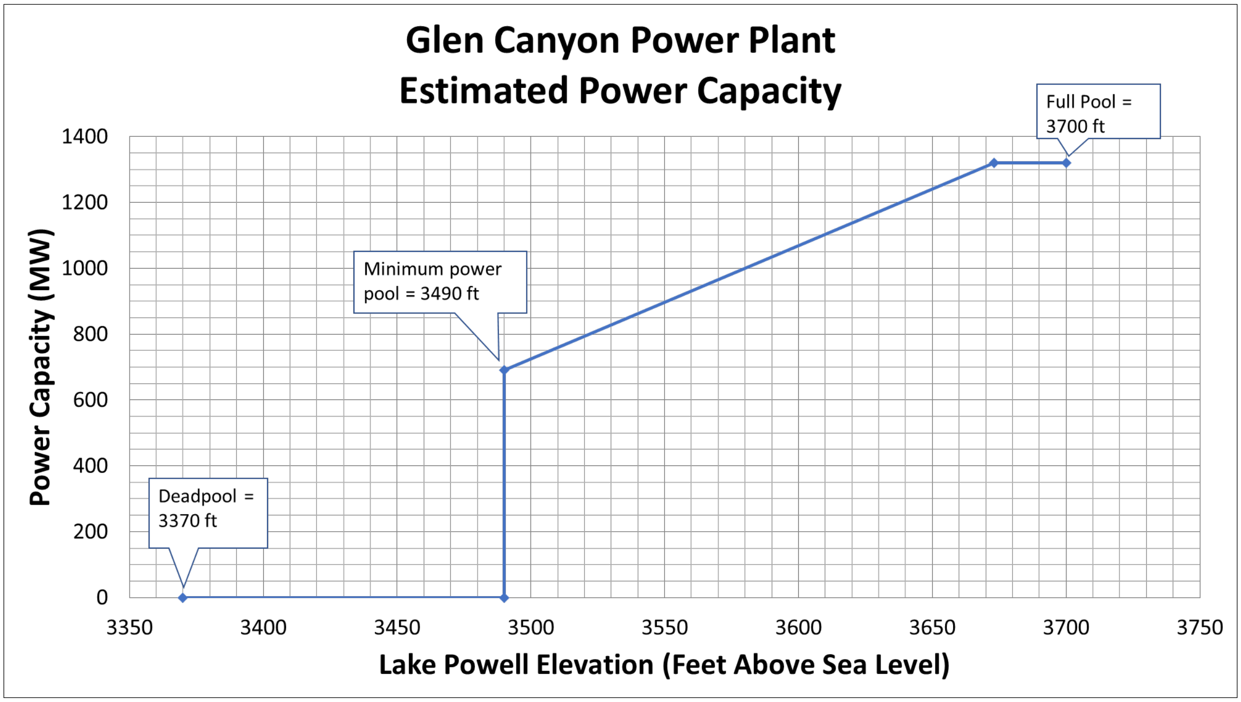
Lake Powell and Glen Canyon Dam

The Glen Canyon Powerplant accounts for approximately 75 percent of the Upper Colorado Basin's annual energy production (Reclamation 2007). Since the 2007 Interim Guidelines were published, the powerplant has undergone projects to improve efficiency, including replacement of all eight turbines (AZCentral 2015). Reclamation also optimized software within the facility, resulting in higher efficiency. Standard operations and maintenance work also have continued throughout this time (Reclamation 2021b).

Despite the improved efficiency, Glen Canyon Powerplant has been heavily impacted by drought conditions in the Basin. The powerplant's capacity decreases as the lake elevation drops. **Figure 3-40** shows the estimated capacity at a range of lower lake elevations. A discussion on modeled capacity is provided below. This decrease in elevation, and therefore head, has been the primary mechanism of reduced power generation since 2007. At the minimum power pool (elevation 3,490 feet), the powerplant has an estimated capacity of 630 MW (Reclamation 2021b).

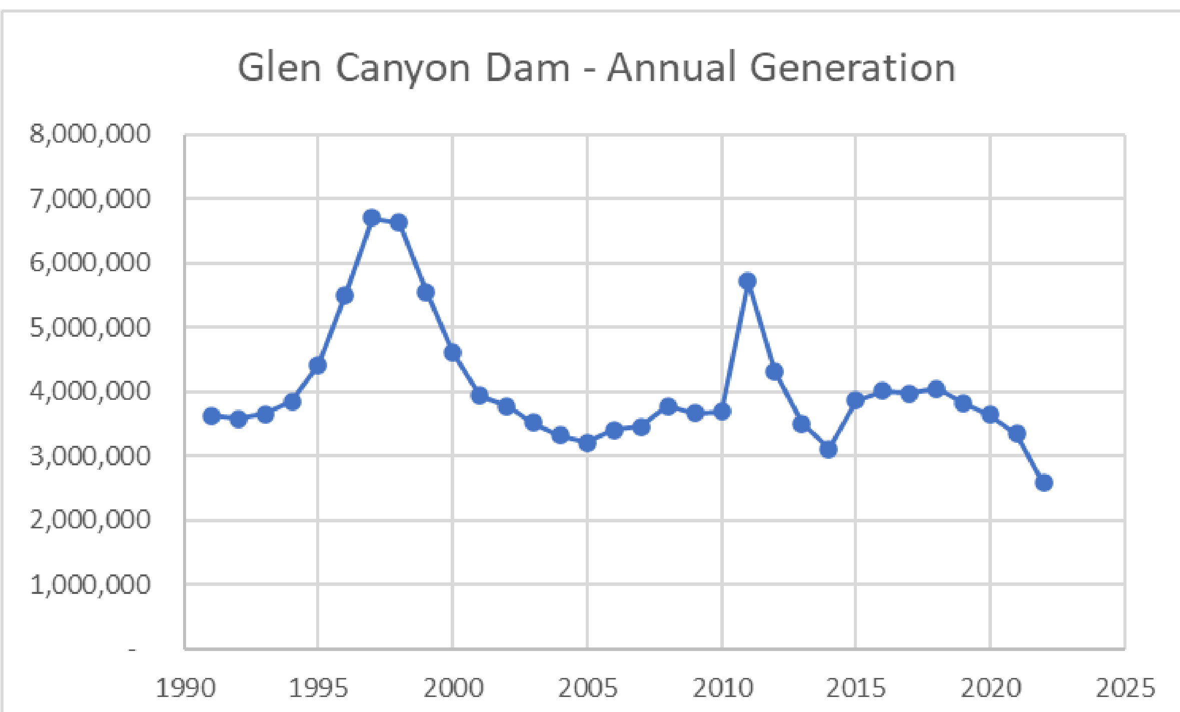
Despite a decrease in head since 2007, sustained annual flows have allowed power generation to continue with an average annual energy production of 3,833 gigawatt hours (GWh) from 2000 through 2020. However, a decrease in flows from 2020 through 2021 resulted in a decline in energy generation (Reclamation 2021b). **Figure 3-41** shows the historical annual generation at Glen Canyon Powerplant from 1991 to 2022.

Figure 3-40
Glen Canyon Powerplant Estimated Power Capacity



Source: Reclamation 2021b

Figure 3-41
Glen Canyon Dam – Annual Generation



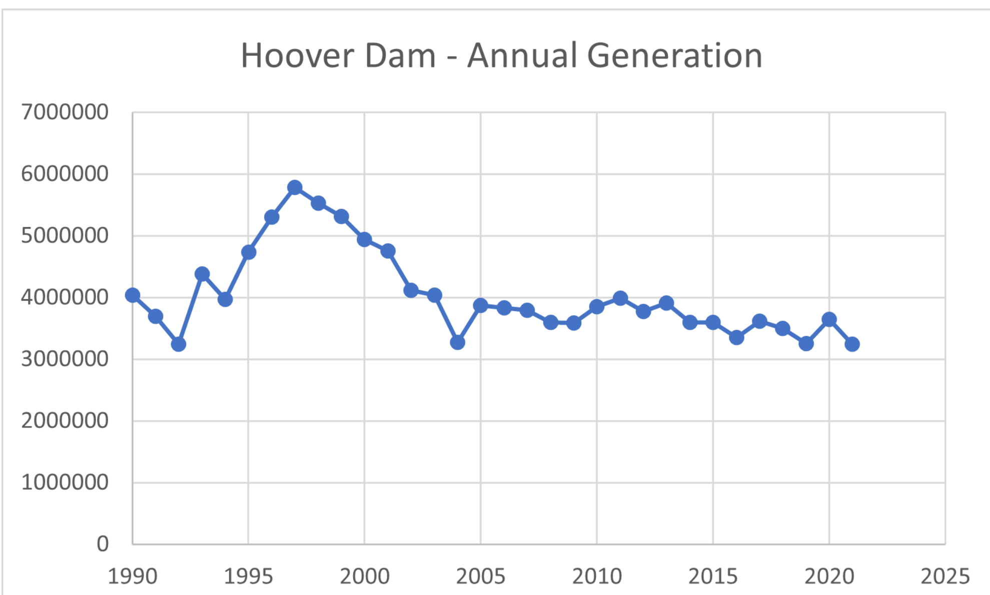
Source: Reclamation 2023b

Lake Mead and Hoover Dam

The Hoover Powerplant remains the largest hydropower-generation facility in the Colorado River Basin. Since the 2007 Interim Guidelines, Reclamation has replaced five existing turbines at the powerplant with "wide-head" turbines that run more efficiently at all reservoir elevations at and above the minimum power pool (8NewsNow 2022). These turbines allow Hoover Dam to produce power at elevations 950 feet and greater. In addition to the upgraded turbines, the Hoover Powerplant's staff has upgraded wicket gates[20] at most units, which allows more water to pass through the turbines. Reclamation has also modernized all unit controls, which has also increased efficiency. The facilities also have undergone typical operations and maintenance (Reclamation 2021b).

Similar to conditions at Glen Canyon, the Hoover Powerplant has experienced significant impacts since 2007 due to drought conditions. **Figure 3-42** shows the historical annual generation at Hoover Powerplant from 1991 to 2022. A decrease in lake elevation has led to a decrease in head, resulting in a lower capacity. **Figure 3-43** shows the relationship between lake elevation and capacity at the Hoover Powerplant. This reduction in head has led to a steady decline in energy production starting in 2015 (Reclamation 2021b).

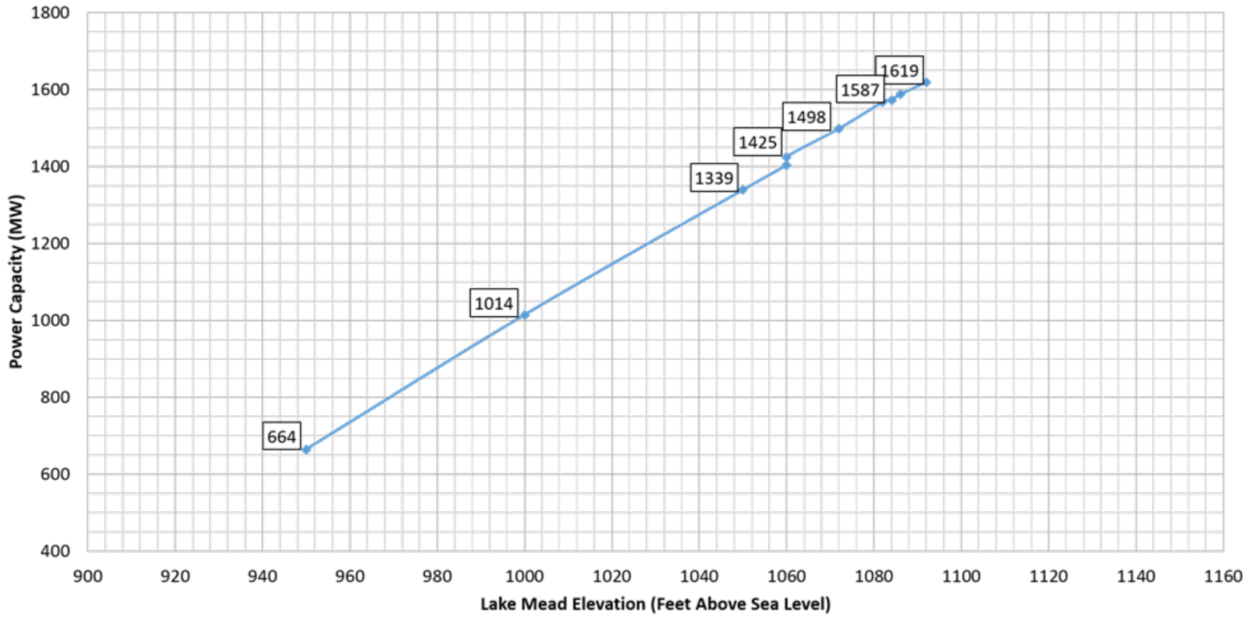
Figure 3-42
Hoover Dam – Annual Generation



Source: Reclamation 2021b

[20] Wicket gates can open and close to allow or stop water from entering the turbines.

Figure 3-43
Low Lake Power Capacity Expectations for Hoover Powerhouse



Source: Reclamation 2021b

A new contract for hydropower was signed in 2018. Under the new contract, the Hoover Powerplant provides power to 46 customers across Arizona, California, and Nevada. All contracts are non-firm, which could impact contractors if droughts result in a further reduction in electric power generation (Reclamation 2007, 2021b).

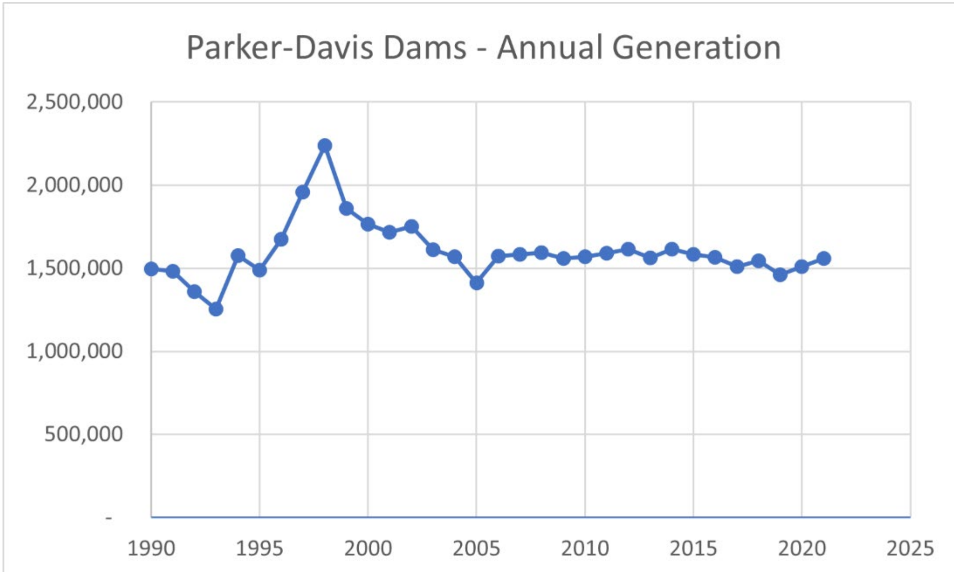
Parker-Davis Project

The Parker-Davis Project consists of the Davis Powerplant with five generators and the Parker Powerplant with four generators (Reclamation 2023b). Since 2007, the Parker-Davis Project facilities have not undergone many significant upgrades. The Parker Powerplant's staff replaced all four turbines between 2004 and 2010. Both powerplants have undergone typical operations and maintenance work since 2007, which has helped with efficiency (Reclamation 2021b).

The drought has had less of an impact on the Parker and Davis Powerplants compared with the Hoover and Glen Canyon Powerplants. This is mostly because the lake reservoirs' (Lake Havasu above Parker Dam and Lake Mohave above Davis Dam) elevations remain relatively constant. Both dams are run of the river, with some flexibility to control releases (Reclamation 2021b). **Figure 3-44** shows the historical combined annual generation at the Parker and Davis Powerplants.

Due to the relatively constant reservoir elevations, the Parker and Davis Powerplants have had little impact on their capacities. The main impact from drought has been a slight reduction in flows. This reduction in flows has caused a reduction in electric power generation, which has impacted the 40 power customers who have contracts with the Parker-Davis Project.

Figure 3-44
Parker-Davis Dam – Annual Generation



Source: Reclamation 2023b

Other Small Hydropower Facilities

Several smaller hydropower facilities are below Parker Dam, including Headgate Rock Dam, Senator Wash, Siphon Drop, and Pilot Knob. Headgate Rock Dam is a run-of-the-river powerplant owned and operated by the BIA. Headgate Rock Dam has an elevation protection, resulting in continued generation during the drought. These facilities have been impacted only slightly by drought since 2007. Due to the elevation protection and run-of the-river operations, the three alternatives would not have a substantial impact on Headgate Rock Powerplant. The other small facilities would not be impacted by any of the alternatives and are, therefore, not analyzed further.

Power Funds

Upper Colorado River Basin Fund

The Colorado River Storage Project (CRSP) Act of 1956 (43 USC 620d)) established the Upper Colorado River Basin Fund (Basin Fund), which collects revenues from the operation of the CRSP facilities and remains available until expended to carry out the project's purposes and operations. The Basin Fund's financial resources are used to repay costs of original investments as well as operation and maintenance of CRSP units and the CRSP transmission system. Money in the Basin Fund can be used to fund various governmental programs (GCDAMP 2020). Maintaining a sufficient Basin Fund balance is critical to operating and maintaining reliable CRSP facilities in delivering water to water users and generating and transmitting power to power customers. Additional contributions and uses of the Basin Fund can be found in Section 3.11.6.1 of the 2007 FEIS; this information is incorporated by reference (Reclamation 2007).

Since the 2007 Interim Guidelines, there have been no changes to the manner in which the Basin Fund operates. WAPA remains responsible for the transmission and marketing of CRSP power, which impacts the finances of the Basin Fund. However, the Basin Fund has been heavily impacted by drought conditions. The reduction of power generation has reduced available resources in the Basin Fund (Reclamation 2021b).

Lower Colorado River Power Funds

The Lower Colorado River Basin Funds consist of three separate funds: the Lower Colorado River Basin Development Fund (Development Fund), the Colorado River Dam Fund (Dam Fund), and the Parker-Davis Account. The Development Fund operates in a similar manner to the Basin Fund, the Dam Fund is specifically tied to Hoover Dam and the Boulder Canyon Project, and the Parker-Davis Account is tied to the Parker-Davis Project facilities. The funds help repay the Central Arizona Project, Lower Colorado River Multi-Species Conservation Program, and the Salinity Control Project (Reclamation 2021b, 2022b). Additional information on how the funds operate can be found in Section 3.11.6.2 of the 2007 FEIS and is incorporated by reference (Reclamation 2007).

All three funds have been impacted by drought conditions since 2007, but it has been a manageable decrease in financial resources. These reductions in financial resources have impacted money delivered to the CAP, Lower Colorado River Multi-Species Conservation Program, and the Salinity Control Project (Reclamation 2021b).

Table 3-45 and **Table 3-46** show the amount of money spent on governmental programs from 2015 to 2020 for Hoover Powerplant and the Parker and Davis Powerplants, respectively.

Table 3-45
Historical Revenue Collections at Hoover Powerplant

Fiscal Year	2015	2016	2017	2018	2019	2020
Lower Colorado River Multi-Species Conservation Program ($1,000 per year)	0.0	0.0	0.0	2,227	2,447	2,547
Development Fund – Arizona ($1,000)	3,543	3,131	2,245	2,865	3,444	2,975
Salinity Control Project – California and Nevada ($1,000)	6,568	7,260	7,328	6,590	6,747	6,583

Source: Reclamation 2021b

Table 3-46
Historical Revenue Collections at Parker-Davis Powerplants

Fiscal Year	2015	2016	2017	2018	2019	2020
Development Fund – Arizona Fund ($1,000)	2,715	2,595	2,844	2,732	2,708	2,895
Salinity Control Project – California and Nevada ($1,000)	1,560	1,576	1,451	1,512	1,632	1,475

Source: Reclamation 2021b

Water Supply Systems

The 2007 Interim Guidelines outline three water supply systems that operate from Lake Powell to Lake Mead: the Navajo Generating Station, the City of Page Water Supply Intake, and the Southern Nevada Water Authority Lake Mead Intake. Since the 2007 Interim Guidelines, the Navajo Generating Station has been decommissioned and is no longer withdrawing water from Lake Powell. The City of Page Water Supply Intake was recently connected to the river outlet works, allowing for continued withdrawals down to a lake elevation of 3,370 feet. It withdraws approximately 2,650 af per year, and the City of Page pays the energy costs associated with pumping the water, including operations and maintenance of the pump station. The Southern Nevada Water Authority Lake Mead Intake was upgraded to allow for water withdrawals down to a reservoir elevation of 825 feet. There have been no changes in operations since 2007.

Surcharges and Ancillary Services

The 2007 Interim Guidelines provide details on surcharges and ancillary services such as regulation and reserve. Surcharges remain in place and help fund government programs by charging customers surcharges on purchases. Regulation depends on ramp rates and acts to provide sufficient generating capacity to serve customer loads. Reserves are used to quickly replace lost generation from an outage. Releases from Glen Canyon and Hoover Powerplants have continued to allow for regulation and reserve to operate since 2007. However, drought conditions could potentially drop releases so low that regulation and reserve are no longer possible. Information on conservation before shortage surcharges, ancillary services, regulation, and reserves can be found in Section 4.11.2.6 of the 2007 FEIS (Reclamation 2007).

3.15.2 Environmental Consequences

This section analyzes the potential effects of the proposed actions on electrical power (or hydropower) resources. The following issues are addressed:

- Impacts on power generation from changes in lake reservoir elevations and releases
- Impacts on the economic value from changes in power generation
- Effects on Upper and Lower Colorado Basin Funds
- Impacts on government programs

Methodology

Reclamation, with the assistance of WAPA, conducted a study of the potential effects of the No Action Alternative and action alternatives on electrical power resources of the Colorado River system that included all major facilities. Reclamation's CRMMS modeling results helped develop potential releases, reservoir elevations, power generation, and economic impacts from the action alternatives. WAPA's GTMax modeling was used to further analyze impacts on the Glen Canyon Powerplant. The results of these analyses are used throughout this section. All tables in this section were produced using results from either the CRMMS or GTMax modeling results.

Impact Analysis Area

The analysis area includes every major hydropower facility along the Colorado River, from Lake Powell to the SIB. Facilities include the Glen Canyon Powerplant, Hoover Powerplant, Davis

Powerplant, and Parker Powerplant. The impact analysis for Parker and Davis Powerplants has been combined because these facilities operate very similarly. Other smaller facilities along the river include Headgate Rock Powerplant, Senator Wash, Siphon Drop, and Pilot Knob. These smaller facilities would not be substantially impacted by the action alternatives and have, therefore, been removed from further analysis.

Assumptions

There were several assumptions made during the modeling process. The assumptions from the CRMMS modeling of the Upper and Lower Basin are covered in **Section 3.3**, Methodology, with additional information in **Section 3.6**, Hydrologic Resources, and **Appendix C**, CRMMS Model Documentation. Following the CRMMS modeling of the Upper Basin, the GTMax modeling was used for releases from Glen Canyon Dam. Results from the GTMax modeling are only calculated for 1 week each month and then replicated for every week of the month. The CRMMS and GTMax models included estimates of the total hydropower value for each dam. Economic impacts on the various basin funds and federal programs can be difficult to accurately model. A qualitative analysis of the impacts is based on the total hydropower value model results.

Impact Indicators

Electrical power resources are typically evaluated based on hydrologic and economic conditions. The following indicators were used for the analysis:

- Reservoir elevation changes determine the amount of head available, which controls both energy and capacity. Monthly reservoir elevation data were used at Lake Powell, Lake Mead, Lake Havasu, and Lake Mohave.
- Penstock water releases are what power the powerplant turbines and lead to power generation. The CRMMS model estimates monthly releases in the Upper and Lower Colorado Basin. The GTMax model estimates hourly releases at Glen Canyon Dam.
- The total hydropower value is an estimation of economic value at each dam. The value is calculated using modeled generation, capacity, rates, and other economic indicators. These values help analyze impacts on operations, basin funds, and customers.

Issue 1: How would lake reservoir elevations and releases impact power generation?

The electrical power-generation analysis is derived from the GTMax model for the Upper Basin and the CRMMS model for the Lower Basin. These models simulate releases and lake reservoir elevations to calculate an estimated generation. Using the modeled annual elevations and releases, the median, 10th, and 90th percentile annual energy-generation statistics were calculated from operating years 2024–2026 for Glen Canyon, Hoover, Parker, and Davis Powerplants using combined data from 80 percent ESP, 90 percent ESP, and 100 percent ESP. These calculations provide an estimated amount of annual generation under dry hydrologic conditions (minimum, 10th percentile), typical conditions (median), and wet hydrologic conditions (90th percentile, maximum).

Summary

Compared with the No Action Alternative, Action Alternatives 1 and 2 result in substantially more power generation at Glen Canyon Powerplant under low hydrology scenarios. This is particularly true in operating years 2025–2026 when lake elevations under the No Action Alternative could drop below the minimum power pool. The difference is more varied at higher hydrologic scenarios due to the possibility of the dams releasing under different operational tiers. The difference was calculated by subtracting the estimated annual generation of the action alternative by the estimated annual generation of the No Action Alternative. This was repeated for every year and every statistical scenario. **Table 3-47** shows the difference in Glen Canyon Powerplant generation under each action alternative compared with the No Action Alternative.

Table 3-47
Difference in Glen Canyon Powerplant Annual Energy Generation (MWh) Compared with the No Action Alternative

	Minimum	10th Percentile	Median	90th Percentile	Maximum
Action Alternative 1					
2024	0	718,138	-204,811	131,850	0
2025	724,394	1,912,703	-16,434	-22,222	485,188
2026	1,523,534	1,995,451	86,293	-115,842	-49,259
Total	**2,247,928**	**4,626,292**	**-134,952**	**-6,214**	**435,929**
Action Alternative 2					
2024	0	791,345	-204,811	131,682	0
2025	836,973	1,919,434	32,154	-22,156	-55,496
2026	1,901,462	2,056,928	97,958	-48,279	207,484
Total	**2,738,435**	**4,767,707**	**-74,699**	**61,247**	**151,988**

Source: WAPA 2023

Annual releases at Lake Mead are higher under the No Action Alternative, leading to less power generation at Hoover Powerplant under Action Alternatives 1 and 2 across all hydrologic scenarios. Action Alternative 2 shows slightly less reduction in generation compared with the No Action Alternative due to the potential additional DROA releases. **Table 3-48** shows the difference in Hoover Powerplant generation under each action alternative compared with the No Action Alternative. The difference was calculated by subtracting the estimated annual generation of the action alternative by the estimated annual generation of the No Action Alternative.

Table 3-48
Difference in Hoover Powerplant Annual Energy Generation (MWh) Compared with the No Action Alternative

	Minimum	10th Percentile	Median	90th Percentile	Maximum
Action Alternative 1					
2024	-761,040	-308,076	-275,205	-163,961	-81,740
2025	-715,290	-599,204	-514,645	-100,004	-51,360
2026	0	651,160	-251,455	34,653	20,300
Total	**-1,476,330**	**-256,120**	**-1,041,305**	**-229,312**	**-112,800**

	Minimum	10th Percentile	Median	90th Percentile	Maximum
Action Alternative 2					
2024	-593,510	-321,236	-299,275	-145,224	-57,550
2025	-715,290	-520,181	-513,955	-68,374	-200,530
2026	0	705,924	-249,175	65,826	-80,200
Total	**-1,308,800**	**-135,493**	**-1,062,405**	**-147,772**	**-338,280**

Source: Reclamation 2023g

Reduced annual releases at both Parker and Davis Powerplants under both action alternatives would result in a combined decrease in generation across all hydrologic scenarios. While elevations would be protected to ensure power generation can continue, the reduced releases would negatively impact generation. Impacts would be greater under low hydrologic scenarios. **Table 3-49** shows the difference in Parker-Davis Powerplants' combined generation under each action alternative compared with the No Action Alternative. The difference was calculated by subtracting the estimated annual generation of the action alternative by the estimated annual generation of the No Action Alternative.

Table 3-49
Difference in Parker-Davis Powerplants Annual Energy Generation (MWh) Compared with the No Action Alternative

	Minimum	10th Percentile	Median	90th Percentile	Maximum
Action Alternative 1					
2024	-91,885	-94,588	-90,457	-64,999	-43,536
2025	-314,347	-265,159	-222,481	-93,745	-51,811
2026	-61,425	-292,451	-171,416	-61,353	-21,766
Total	**-467,657**	**-652,198**	**-484,354**	**-220,097**	**-117,113**
Action Alternative 2					
2024	-123,734	-127,794	-123,356	-74,846	-59,678
2025	-314,369	-291,242	-262,824	-113,477	-88,461
2026	3,497	-320,149	-211,266	-72,342	-62,761
Total	**-434,606**	**-739,185**	**-597,446**	**-260,665**	**-210,900**

Source: Reclamation 2023g

Overall, the action alternatives result in substantially more generation under low hydrologic conditions. This is mainly the result of elevation protections at Lake Powell. The action alternatives result in a decrease in generation during wetter hydrologic conditions due to the increased releases under the No Action Alternative. **Table 3-50** shows the total difference in energy generation across all four powerplants analyzed.

Table 3-50
Total Difference in Annual Energy Generation (MWh) Compared with the No Action Alternative

	Minimum	10th Percentile	Median	90th Percentile	Maximum
Action Alternative 1					
2024	-852,925	315,474	-570,473	-97,110	-125,276
2025	-305,243	1,048,340	-753,560	-215,971	382,017
2026	1,462,109	2,354,160	-336,578	-142,542	-50,725
Total	**303,941**	**3,717,974**	**-1,660,611**	**-455,623**	**206,016**
Action Alternative 2					
2024	-717,244	342,315	-627,442	-88,388	-117,228
2025	-192,686	1,108,011	-744,625	-204,007	-344,487
2026	1,904,959	2,442,703	-362,483	-54,795	64,523
Total	**995,029**	**3,893,029**	**-1,734,550**	**-347,190**	**-397,192**

Source: Reclamation 2023g; WAPA 2023

No Action Alternative

Under the No Action Alternative, annual releases from Lake Powell and Lake Mead would continue as outlined in the 2007 Interim Guidelines. At these rates, under dry hydrologic conditions, the likelihood of water elevations dropping below the minimum power pool at Lake Powell and Lake Mead rises drastically. Elevation protections at Parker and Davis Dams would allow generation to continue; however, it would drop significantly as flows decrease over time.

The following tables show the values for annual energy generation at the four analyzed powerplants for the operating years 2024–2026. These values represent the minimum, maximum, median, 10th percentile, and 90th percentile of the modeled annual generation values. These values represent dry hydrologic scenarios (minimum, 10th percentile), typical conditions (median), and wet hydrologic scenarios (90th percentile, maximum). These tables help show the trend of generation over the 3 years analyzed.

Table 3-51 shows the annual generation at Glen Canyon Powerplant under the No Action Alternative. Under dry hydrologic conditions, lake elevations quickly drop below minimum power pool, resulting in a complete halt in generation. Under more typical hydrologic conditions, generation would continue at a relatively stable rate, but still well below historical rates, as shown in **Figure 3-41**. Under wetter hydrologic conditions, generation at Glen Canyon Dam would begin to increase with the ability for higher releases.

Table 3-51
No Action Alternative – Glen Canyon Annual Energy Generation

	Minimum	10th Percentile	Median	90th Percentile	Maximum
2024	0	607,984	2,631,335	2,952,797	3,609,284
2025	0	0	2,733,138	3,551,216	4,990,953
2026	0	0	2,714,932	3,772,168	5,329,671

Source: WAPA 2023

Table 3-52 shows annual generation at Hoover Powerplant under the No Action Alternative. Similar to Glen Canyon, under dry hydrologic conditions, the lake elevation would rapidly decline, resulting in severely diminished generation in 2026, with the potential for elevations to drop below minimum power pool. Under typical or wet hydrologic conditions, generation would maintain at a relatively similar rate across the 3 operating years.

Table 3-52
No Action Alternative – Hoover Dam Annual Energy Generation

	Minimum	10th Percentile	Median	90th Percentile	Maximum
2024	2,261,650	2,551,860	2,816,735	3,148,790	3,478,980
2025	715,290	2,158,103	2,667,670	3,059,795	3,542,470
2026	0	907,162	2,662,905	3,111,136	3,811,310

Source: Reclamation 2023g

Table 3-53 shows annual combined generation for the Parker and Davis Powerplants under the No Action Alternative. Due to the elevation protections at both dams, generation is able to continue at a relatively constant rate across most hydrologic conditions. There would be minor changes in generation across the hydrologic scenarios but a negligible change throughout the 3 operating years. However, under the absolute driest hydrologic conditions, generation would start to decrease rapidly from operating year 2025–2026. This is likely due to a significant decrease in releases.

Table 3-53
No Action Alternative – Parker-Davis Annual Energy Generation

	Minimum	10th Percentile	Median	90th Percentile	Maximum
2024	1,298,674	1,390,061	1,466,151	1,548,398	1,666,832
2025	1,254,596	1,349,356	1,425,099	1,510,693	1,632,800
2026	862,966	1,361,427	1,445,894	1,531,410	1,672,721

Source: Reclamation 2023g

Table 3-54 shows the combined total annual generation across all four powerplants under the No Action Alternative. The trend typically mirrors those from Glen Canyon and Hoover Powerplants as they exhibit the dominant changes across hydrologic scenarios and operating years.

Table 3-54
No Action Alternative – Total Annual Energy Generation

	Minimum	10th Percentile	Median	90th Percentile	Maximum
2024	3,560,324	4,549,905	6,914,221	7,649,985	8,755,096
2025	1,969,886	3,507,459	6,825,907	8,121,704	10,166,223
2026	862,966	2,268,589	6,823,731	8,414,714	10,813,702

Source: Reclamation 2023g; WAPA 2023

Action Alternative 1

Under Action Alternative 1, elevations at Lake Powell would be protected at 3,500 feet, allowing hydroelectric generation to continue at Glen Canyon Powerplant even under the driest hydrologic conditions. This would result in a considerably smaller chance of dropping below the minimum power pool at Glen Canyon Dam. However, protecting elevations at Lake Powell could result in a decrease in elevation at Lake Mead. This would lead to significantly less generation at the Hoover Powerplant. Releases at Hoover Dam would also be decreased under Action Alternative 1, further impacting generation.

The Parker and Davis Powerplants would be impacted by reduced releases; however, because lake reservoir elevations are protected, generation would continue. Releases from the dams would be the major factor for impacts on generation.

The following tables show the values for annual energy generation at the four analyzed powerplants for operating years 2024–2026. These values represent the minimum, maximum, median, 10th percentile, and 90th percentile of the modeled annual generation values. These values represent dry hydrologic scenarios (minimum, 10th percentile), typical conditions (median), and wet hydrologic scenarios (90th percentile, maximum). These tables help show the trend of generation over the 3 years analyzed.

Table 3-55 shows the values for annual energy generation at the Glen Canyon Powerplant for operating years 2024–2026 under Action Alternative 1. Under most hydrologic scenarios, generation would continue over the 3 operating years at a relatively constant rate. There would be a slight uptick in generation between 2024 and 2025 as elevation levels are raised to protect 3,500 feet. Under the driest hydrologic conditions, generation would not be possible in operating year 2024 because lake reservoir elevations would begin below minimum power pool. Over time, the elevations would be raised to allow for generation to begin again.

Table 3-55
Action Alternative 1 – Glen Canyon Annual Energy Generation

	Minimum	10th Percentile	Median	90th Percentile	Maximum
2024	0	1,326,122	2,426,524	2,829,203	3,084,647
2025	724,394	1,912,703	2,716,705	3,233,171	3,528,994
2026	1,523,534	1,995,451	2,801,225	3,466,217	3,656,326

Source: WAPA 2023

Table 3-56 shows the annual generation at Hoover Powerplant under Action Alternative 1. Under typical and wet hydrologic conditions, generation would continue at a similar rate. However, under drier hydrologic conditions, the elevation protection at Lake Powell would result in a decrease in elevations and releases at Hoover Powerplant, resulting in a substantial decrease in generation in operating years 2025–2026. Under the driest hydrologic conditions, elevations would drop below minimum power pool prior to operating year 2025, resulting in a complete halt in generation.

Table 3-56
Action Alternative 1 – Hoover Powerplant Annual Energy Generation

	Minimum	10th Percentile	Median	90th Percentile	Maximum
2024	1,500,610	2,243,784	2,541,530	2,984,829	3,397,240
2025	0	1,558,899	2,153,025	2,959,791	3,491,110
2026	0	1,558,322	2,411,450	3,145,789	3,831,610

Source: Reclamation 2023g

Table 3-57 shows the annual combined generation at Parker and Davis Powerplants under Action Alternative 1. Generation rates would remain similar under most hydrologic scenarios as the elevation protection allows for continued generation at both powerplants. Under the driest hydrologic conditions, a larger decline in generation would occur as drought conditions continue to worsen and releases continue to decrease.

Table 3-57
Action Alternative 1 – Parker-Davis Annual Energy Generation

	Minimum	10th Percentile	Median	90th Percentile	Maximum
2024	1,206,789	1,295,473	1,375,694	1,483,399	1,623,296
2025	940,249	1,084,197	1,202,618	1,416,948	1,580,989
2026	801,541	1,068,976	1,274,478	1,470,057	1,650,955

Source: Reclamation 2023g

Table 3-58 shows the total combined annual generation across all four powerplants under Action Alternative 1. There are substantial decreases in total generation between the hydrologic scenarios. However, with the exception of the driest scenarios, the generation rates remain relatively constant over the 3 operating years. The wetter hydrologic conditions result in a continued increase in generation each year. The driest hydrologic scenarios result in variable generation as Lake Powell and Lake Mead experience a drop below minimum power pool at some point during the 3 years.

Table 3-58
Action Alternative 1 – Total Annual Energy Generation

	Minimum	10th Percentile	Median	90th Percentile	Maximum
2024	2,707,399	4,865,379	6,343,748	7,297,431	8,105,183
2025	1,664,643	4,555,799	6,072,348	7,609,910	8,601,093
2026	2,325,075	4,622,749	6,487,153	8,082,063	9,138,891

Source: Reclamation 2023g; WAPA 2023

Action Alternative 2

Under Action Alternative 2, different allocations would redirect water below the Hoover Powerplant. This would have no impact on hydroelectric generation at the Glen Canyon and Hoover Powerplants compared with Action Alternative 1. There would be slight changes in impacts on generation at the Parker and Davis Powerplants compared with Action Alternative 1.

The potential DROA contributions would result in higher lake elevations and releases at Lake Powell and Lake Mead. These conditions would lead to greater generation potential at the Glen Canyon and Hoover Powerplants. The potential DROA contributions would have slight impacts on the Parker and Davis Powerplants.

The following tables show the values for annual energy generation at the four analyzed powerplants for operating years 2024–2026. These values represent the minimum, maximum, median, 10th percentile, and 90th percentile of the modeled annual generation values. These values represent dry hydrologic scenarios (minimum, 10th percentile), typical conditions (median), and wet hydrologic scenarios (90th percentile, maximum). These tables help show the trend of generation over the 3 years analyzed.

Table 3-59 shows the values for annual energy generation at the Glen Canyon Powerplant for operating years 2024–2026 under Action Alternative 2. The trends are nearly identical as those under Action Alternative 1 with slightly higher generations across all hydrologic scenarios; this is because the potential DROA contributions allow for higher elevation and greater releases. Even with the potential DROA contributions, the driest hydrologic scenarios would result in lake elevations below minimum power pool in operating year 2024, resulting in a complete halt in generation.

Table 3-59
Action Alternative 2 – Glen Canyon Annual Energy Generation

	Minimum	10th Percentile	Median	90th Percentile	Maximum
2024	0	1,399,329	1,989,596	2,426,524	2,829,178
2025	836,973	1,919,434	2,218,021	2,765,292	3,231,255
2026	1,901,462	2,056,928	2,408,524	2,812,890	3,462,758

Source: WAPA 2023g

Table 3-60 shows the annual energy generation at the Hoover Powerplant under Action Alternative 2. The trends are nearly identical as under Action Alternative 1 with slightly higher generations across all hydrologic scenarios; this is because the potential DROA contributions allow for higher elevation and greater releases. Even with the potential DROA contributions, the driest hydrologic scenarios would result in lake elevations below minimum power pool in operating years 2025 and 2026, resulting in a complete halt in generation.

Table 3-60
Action Alternative 2 – Hoover Annual Energy Generation

	Minimum	10th Percentile	Median	90th Percentile	Maximum
2024	1,668,140	2,230,624	2,517,460	3,003,566	3,421,430
2025	0	1,637,922	2,153,715	2,991,421	3,341,940
2026	0	1,613,086	2,413,730	3,176,962	3,731,110

Source: Reclamation 2023g

Table 3-61 shows the combined annual energy generation at the Parker and Davis Powerplants under Action Alternative 2. The trends are nearly identical as under Action Alternative 1 with slightly higher generations across all hydrologic scenarios; this is because the potential DROA contributions allow for higher elevation and greater releases.

Table 3-61
Action Alternative 2 – Parker-Davis Annual Energy Generation

	Minimum	10th Percentile	Median	90th Percentile	Maximum
2024	1,174,940	1,262,267	1,342,795	1,473,552	1,607,154
2025	940,227	1,058,114	1,162,275	1,397,216	1,544,339
2026	866,463	1,041,278	1,234,628	1,459,068	1,609,960

Source: Reclamation 2023g

Table 3-62 shows the values for total combined annual energy generation at all four powerplants under Action Alternative 2. The trends are nearly identical as under Action Alternative 1 with slightly higher generations across all hydrologic scenarios; this is because the potential DROA contributions allow for higher elevation and greater releases.

Table 3-62
Action Alternative 2 – Total Annual Energy Generation

	Minimum	10th Percentile	Median	90th Percentile	Maximum
2024	2,843,080	4,892,220	5,849,851	6,903,642	7,857,762
2025	1,777,200	4,615,470	5,534,011	7,153,929	8,117,534
2026	2,767,925	4,711,292	6,056,882	7,448,920	8,803,828

Source: Reclamation 2023g; WAPA 2023

Cumulative Effects

The potential operational changes included in the Glen Canyon Dam/Smallmouth Bass flow options would result in a substantial decrease in power generation at the Glen Canyon Powerplant. The flow options would alter how water is released through Glen Canyon Dam by rerouting releases through the river outlet works as opposed to the power-generating penstocks. This would result in a cumulative negative impact on generation across all alternatives outlined in the SEIS. The flow options would have minor impacts on dry hydrologic scenarios under the No Action Alternative, because lake elevations would drop below minimum power pool and all releases would be through the river outlet works. Overall, monthly and annual volume releases from Lake Powell would not change; therefore, no additional impacts would occur at any downstream powerplants.

Issue 2: How would changes in lake reservoir elevations impact capacity?

The capacity analysis is derived from the GTMax model for the Upper Basin and the CRMMS model for the Lower Basin. These models simulate lake reservoir elevations and generator availability to calculate an estimated capacity. Using the modeled annual elevations and unit availability, the median, 10th, and 90th percentile monthly capacity statistics were calculated from operating years 2024–2026 for Glen Canyon, Hoover, Parker, and Davis Powerplants using combined data from 80 percent ESP, 90 percent ESP, and 100 percent ESP. These calculations provide an estimated amount of annual generation under dry hydrologic conditions (minimum, 10th percentile), typical conditions (median), and wet hydrologic conditions (90th percentile, maximum). WAPA and Reclamation used the estimated capacity for the month of August as a yearly representation due to the peak energy demands and available capacity during that month.

The capacity at the Parker and Davis Powerplants does not fluctuate greatly due to the lake reservoir elevation protections. It is expected that these capacities will remain relatively constant across all alternatives. Therefore, the Parker and Davis Powerplants are not included in the capacity analysis.

Summary

Compared with the No Action Alternative, Action Alternatives 1 and 2 result in a substantially greater capacity at Glen Canyon Powerplant under low hydrologic scenarios. This is particularly true in operating years 2025–2026 when lake elevations under the No Action Alternative could drop below the minimum power pool. The difference is more varied at higher hydrologic scenarios due to the possibility of the dams releasing under different operational tiers resulting in varied lake elevations. The difference was calculated by subtracting the estimated August capacity of the action alternative by the estimated August capacity of the No Action Alternative. This was repeated for every year and every statistical scenario. **Table 3-63** shows the difference in Glen Canyon Powerplant capacity under each action alternative compared with the No Action Alternative.

Table 3-63
Difference in Glen Canyon Powerplant August Capacity (MW) Compared with the No Action Alternative

	Minimum	10th Percentile	Median	90th Percentile	Maximum
Action Alternative 1					
August 2024	0	193	24	74	82
August 2025	58	322	68	47	60
August 2026	80	338	68	26	-1
Action Alternative 2					
August 2024	0	233	24	74	82
August 2025	79	328	71	54	1
August 2026	295	343	68	31	71

Source: WAPA 2023

Lake reservoir elevations at Lake Mead are variable across the alternatives at different hydrologic conditions, resulting in variable capacity. Under the driest hydrologic conditions, capacity is greatest in operating year 2024 under the No Action Alternative; however, all alternatives result in a drop below minimum power pool and a drop to zero capacity in operating years 2025 and 2026. For all remaining hydrologic scenarios, capacity under the No Action Alternative outperforms both action alternatives in operating year 2024. However, capacity under both action alternatives outperforms the No Action Alternative under the remaining operating years. **Table 3-64** shows the difference in Hoover Powerplant capacity under each action alternative compared with the No Action Alternative. The difference was calculated by subtracting the estimated August capacity of the action alternative by the estimated August capacity of the No Action Alternative.

Table 3-64
Difference in Hoover Powerplant August Capacity (MW) Compared with the No Action Alternative

	Minimum	10th Percentile	Median	90th Percentile	Maximum
Action Alternative 1					
August 2024	-719	-48	-34	-1	6
August 2025	0	49	76	58	21
August 2026	0	754	163	141	34
Action Alternative 2					
August 2024	-719	-33	-31	-6	0
August 2025	0	54	77	55	20
August 2026	0	756	181	127	54

Source: Reclamation 2023g

No Action Alternative

Under the No Action Alternative, annual operations at Lake Powell and Lake Mead would continue as outlined in the 2007 Interim Guidelines. At these rates, under dry hydrologic conditions, the likelihood of water elevations dropping below the minimum power pool at Lake Powell and Lake Mead rises drastically.

The following tables show the values for August capacity at Glen Canyon and Hoover Powerplants for operating years 2024–2026. These values represent the minimum, maximum, median, 10th percentile, and 90th percentile of the modeled August capacity values. These values represent dry hydrologic scenarios (minimum, 10th percentile), typical conditions (median), and wet hydrologic scenarios (90th percentile, maximum). These tables help show the trend of potential capacity over the 3 years analyzed.

Table 3-65 shows the August capacity at Glen Canyon Powerplant under the No Action Alternative. Under dry hydrologic conditions, lake elevations drop below minimum power pool, resulting in a complete halt in capacity. Under more typical hydrologic conditions, capacity would continue at a relatively stable rate, but still well below historical levels. Under wetter hydrologic conditions, capacity at Glen Canyon Dam would begin to increase with the potential for higher lake reservoir elevations.

Table 3-65
No Action Alternative – Glen Canyon August Capacity

	Minimum	10th Percentile	Median	90th Percentile	Maximum
August 2024	0	0	460	572	620
August 2025	0	0	478	605	926
August 2026	0	0	483	636	928

Source: WAPA 2023

Table 3-66 shows August capacity at Hoover Powerplant under the No Action Alternative. Similar to Glen Canyon, under dry hydrologic conditions, the lake elevation would rapidly decline, resulting in severely diminished capacity, with the potential for elevations to drop below minimum power pool in operating years 2025 and 2026. Under typical or wet hydrologic conditions, capacity would maintain at a relatively similar rate across the 3 operating years.

Table 3-66
No Action Alternative – Hoover Dam August Capacity

	Minimum	10th Percentile	Median	90th Percentile	Maximum
August 2024	719	876	1,030	1,182	1,319
August 2025	0	700	991	1,187	1,415
August 2026	0	0	971	1,174	1,464

Source: Reclamation 2023g

Action Alternative 1

Under Action Alternative 1, elevations at Lake Powell would be protected at 3,500 feet, allowing for continued capacity at Glen Canyon Powerplant even under the driest hydrologic conditions. This alternative would result in a considerably smaller chance of dropping below the minimum power pool at Glen Canyon Dam. However, protecting elevations at Lake Powell could result in an immediate decrease in elevation at Lake Mead in operating year 2024. This would result in lower capacity at Hoover Powerplant, but a recovery of capacity in operating years 2025 and 2026.

The following tables show the values for August capacity at Glen Canyon and Hoover Powerplants for operating years 2024–2026. These values represent the minimum, maximum, median, 10th percentile, and 90th percentile of the modeled August capacity values. These values represent dry hydrologic scenarios (minimum, 10th percentile), typical conditions (median), and wet hydrologic scenarios (90th percentile, maximum). These tables help show the trend of capacity over the 3 years analyzed.

Table 3-67 shows the values for August capacity at the Glen Canyon Powerplant for operating years 2024–2026 under Action Alternative 1. Under most hydrologic scenarios, capacity would continue over the 3 operating years. There would be a slight uptick in capacity over the 3 years as elevation levels are raised to protect 3,500 feet. Under the driest hydrologic conditions, capacity would not be possible in operating year 2024 because lake reservoir elevations would begin below minimum power pool. Over time, the elevations would be raised to allow for capacity to begin again.

Table 3-67
Action Alternative 1 – Glen Canyon August Capacity

	Minimum	10th Percentile	Median	90th Percentile	Maximum
August 2024	0	193	484	646	702
August 2025	58	322	545	652	985
August 2026	80	338	551	662	927

Source: WAPA 2023

Table 3-68 shows the August capacity at Hoover Powerplant under Action Alternative 1. Under typical and wet hydrologic conditions, generation would continue at a similar rate. However, under the driest hydrologic conditions, the elevation protection at Lake Powell would result in elevations at Hoover Dam dropping below minimum power pool, resulting in a halt of capacity.

Table 3-68
Action Alternative 1 – Hoover Powerplant August Capacity

	Minimum	10th Percentile	Median	90th Percentile	Maximum
August 2024	0	828	996	1,181	1,325
August 2025	0	749	1,067	1,245	1,436
August 2026	0	754	1,134	1,315	1,498

Source: Reclamation 2023g

Action Alternative 2

Under Action Alternative 2, different allocations would redirect water below the Hoover Powerplant. This would have no impact on capacity at the Glen Canyon and Hoover Powerplants compared with Action Alternative 1.

The potential DROA contributions would result in higher lake elevations at Lake Powell and Lake Mead. These conditions would lead to slightly greater potential capacity at the Glen Canyon and Hoover Powerplants across most hydrologic conditions compared with Action Alternative 1.

The following tables show the values for August capacity at Glen Canyon and Hoover Powerplants for operating years 2024–2026. These values represent the minimum, maximum, median, 10th percentile, and 90th percentile of the modeled August capacity. These values represent dry hydrologic scenarios (minimum, 10th percentile), typical conditions (median), and wet hydrologic scenarios (90th percentile, maximum). These tables help show the trend of capacity over the 3 years analyzed.

Table 3-69 shows the values for August capacity at the Glen Canyon Powerplant for operating years 2024–2026 under Action Alternative 2. The trends are nearly identical as Action Alternative 1 with higher capacity across all hydrologic scenarios because the potential DROA contributions allow for higher elevation and greater releases. Even with the potential DROA contributions, the driest hydrologic scenarios would result in lake elevations below minimum power pool in operating year 2024, resulting in a complete halt in capacity.

Table 3-69
Action Alternative 2 – Glen Canyon August Capacity

	Minimum	10th Percentile	Median	90th Percentile	Maximum
August 2024	0	233	484	646	702
August 2025	79	328	548	659	927
August 2026	295	343	551	666	999

Source: WAPA 2023g

Table 3-70 shows the August capacity at the Hoover Powerplant under Action Alternative 2. The trends are nearly identical as under Action Alternative 1 with slightly higher generations across all hydrologic scenarios; this is because the potential DROA contributions allow for higher elevation. Even with the potential DROA contributions, the driest hydrologic scenarios would result in lake elevations below minimum power pool in all operating years, resulting in a complete halt in capacity.

Table 3-70
Action Alternative 2 – Hoover Annual Energy Generation

	Minimum	10th Percentile	Median	90th Percentile	Maximum
August 2024	0	843	999	1,176	1,319
August 2025	0	754	1,068	1,242	1,435
August 2026	0	756	1,152	1,301	1,518

Source: Reclamation 2023g

Issue 3: How would changes in power generation and capacity impact the total hydropower value?

The total hydropower value analysis is also derived from the GTMax model for the Upper Basin and the CRMMS model for the Lower Basin. Given the calculated energy generation and capacity, estimates can be made on the average annual total hydropower value for each powerplant. Economic modeling from Reclamation and WAPA uses an hourly operation schedule that maximizes the economic value of hydropower generation. Hourly pricing data used in WAPA's study are derived from the Palo Verde hub and supplemented by other sources. Using the modeled energy-generation values, the minimum, median, maximum, 10th percentile, and 90th percentile annual total hydropower value statistics were calculated for operating years 2024 to 2026 for the Glen Canyon, Hoover, Parker, and Davis Powerplants using combined data from 80 percent ESP, 90 percent ESP, and 100 percent ESP. These calculations provide an estimated amount of annual hydropower value under dry hydrologic conditions (minimum, 10th percentile), typical conditions (median), and wet hydrologic conditions (90th percentile, maximum).

Summary

Action Alternatives 1 and 2 result in more financial resources at Glen Canyon Powerplant when compared with the No Action Alternative. The difference is substantially larger under low hydrologic scenarios. This increase is particularly apparent in operating years 2025–2026 when lake elevations under the No Action Alternative could drop significantly and revenue would decrease proportionally. **Table 3-71** shows the difference in the Glen Canyon Powerplant under each action alternative when compared with the No Action Alternative.

Table 3-71
Difference in the Glen Canyon Powerplant's Total Hydropower Value Compared with the No Action Alternative (Thousands of Dollars)

	Minimum	10th Percentile	Median	90th Percentile	Maximum
Action Alternative 1					
2024	$0	$40,872	-$12,461	$19,071	$0
2025	$64,414	$149,301	$4,557	-$712	$45,815

	Minimum	10th Percentile	Median	90th Percentile	Maximum
2026	$109,581	$161,050	$11,338	-$6,457	$841
Total	**$173,995**	**$351,223**	**$3,434**	**$11,902**	**$46,656**
Action Alternative 2					
2024	$0	$46,496	-$12,461	$19,056	$0
2025	$72,260	$153,173	$7,207	-$719	-$5,119
2026	$142,740	$165,527	$12,829	-$2,101	$24,958
Total	**$215,000**	**$365,196**	**$7,575**	**$16,236**	**$19,839**

Source: WAPA 2023

Reduced generation under the action alternatives would result in a decrease in hydropower value across most hydrologic scenarios at the Hoover Powerplant when compared with the No Action Alternative. The difference is substantially larger under the driest and typical hydrologic conditions. **Table 3-72** shows the difference in the Hoover Powerplant under each action alternative when compared with the No Action Alternative.

Table 3-72
Difference in the Hoover Powerplant's Total Hydropower Value Compared with the No Action Alternative (Thousands of Dollars)

	Minimum	10th Percentile	Median	90th Percentile	Maximum
Action Alternative 1					
2024	-$136,717	-$36,591	-$31,303	-$17,365	-$9,202
2025	-$92,615	-$64,913	-$51,341	-$5,002	-$4,235
2026	$0	$109,828	-$15,470	$12,972	$4,776
Total	**-$229,332**	**$8,324**	**-$98,114**	**-$9,395**	**-$8,661**
Action Alternative 2					
2024	-$101,021	-$38,741	-$35,647	-$16,329	-$6,829
2025	-$92,615	-$55,141	-$52,773	-$3,588	-$22,587
2026	$0	$115,557	-$16,487	$14,060	-$5,888
Total	**-$193,636**	**$21,675**	**-$104,907**	**-$5,857**	**-$35,304**

Source: Reclamation 2023g

The combined reduced generation under the action alternatives would result in a decrease in hydropower value across all hydrologic scenarios at the Parker and Davis Powerplants when compared with the No Action Alternative. The difference is substantially larger under the drier and typical hydrologic conditions. **Table 3-73** shows the difference in the combined Parker and Davis Powerplants under each action alternative when compared with the No Action Alternative.

Table 3-73
Change in the Parker-Davis Powerplants' Total Hydropower Value Compared with the No Action Alternative (Thousands of Dollars)

	Minimum	10th Percentile	Median	90th Percentile	Maximum
Action Alternative 1					
2024	-$8,909	-$9,443	-$8,984	-$6,545	-$4,548
2025	-$32,397	-$27,509	-$22,320	-$9,077	-$4,918
2026	-$13,082	-$28,462	-$16,442	-$5,625	-$1,741
Total	**-$54,388**	**-$65,414**	**-$47,746**	**-$21,247**	**-$11,207**
Action Alternative 2					
2024	-$13,079	-$13,592	-$13,030	-$7,888	-$6,675
2025	-$33,387	-$30,543	-$27,003	-$11,595	-$9,365
2026	-$6,862	-$31,456	-$20,883	-$7,059	-$5,997
Total	**-$53,328**	**-$75,591**	**-$60,916**	**-$26,542**	**-$22,037**

Source: Reclamation 2023g

Table 3-74 combines the total hydropower value for all four powerplants to analyze overall economic impacts under the action alternatives when compared with the No Action Alternative. Under the action alternatives, a combined increase in generation under the drier hydrologic conditions leads to an increase in total hydropower value when compared with the No Action Alternative. However, under the driest, typical, and wet hydrologic conditions, a decrease in combined generation leads to a decrease in total hydropower value. These results are highly variable and show the complexity of total hydropower value.

Table 3-74
Total Change in Hydropower Value Compared with the No Action Alternative (Thousands of Dollars)

	Minimum	10th Percentile	Median	90th Percentile	Maximum
Action Alternative 1					
2024	-$145,626	-$5,162	-$52,748	-$4,839	-$13,750
2025	-$60,598	$56,879	-$69,104	-$14,791	$36,662
2026	$96,499	$242,416	-$20,574	$890	$3,876
Total	**-$109,725**	**$294,133**	**-$142,426**	**-$18,740**	**$26,788**
Action Alternative 2					
2024	-$114,100	-$5,837	-$61,138	-$5,161	-$13,504
2025	-$53,742	$67,489	-$72,569	-$15,902	-$37,071
2026	$135,878	$249,628	-$24,541	$4,900	$13,073
Total	**-$31,964**	**$311,280**	**-$158,248**	**-$16,163**	**-$37,502**

Source: Reclamation 2023g; WAPA 2023

No Action Alternative

Under the No Action Alternative, annual releases from Lake Powell and Lake Mead would continue as outlined in the 2007 Interim Guidelines. At these rates, the likelihood of water elevations dropping below the minimum power pool at Lake Powell and Lake Mead rises drastically. As lake elevations decline, generation and capacity would decrease and halt as soon as elevations drop below the minimum power pool. Total hydropower value trends typically mirror generation and capacity trends; therefore, when generation and capacity are reduced or stop, the total hydropower value is also reduced or halted. Therefore, the total hydropower value is much lower under low hydrological scenarios.

The following tables show the annual total hydropower value at the four analyzed powerplants for operating years 2024–2026. These values represent the minimum, maximum, median, 10th percentile, and 90th percentile of the modeled annual generation values. These values represent dry hydrologic scenarios (minimum, 10th percentile), typical conditions (median), and wet hydrologic scenarios (90th percentile, maximum). These tables help show the trend of hydropower value over the 3 years analyzed.

Table 3-75 shows the annual total hydropower value at the Glen Canyon for operating years 2024–2026 under the No Action Alternative. Generation and capacity are near or below minimum power pool throughout the drier hydrologic conditions, resulting in a near or complete halt in total hydropower value. At typical and wet hydrologic conditions, the total hydropower value remains relatively consistent across the 3 operating years with slight differences between the hydrologic conditions.

Table 3-75
No Action Alternative – Glen Canyon Dam Annual Hydropower Value (Thousands of Dollars)

	Minimum	10th Percentile	Median	90th Percentile	Maximum
2024	$0	$69,593	$224,362	$239,992	$256,214
2025	$0	$0	$230,664	$252,992	$298,622
2026	$0	$0	$218,813	$254,945	$301,780
Total	**$0**	**$69,593**	**$673,839**	**$747,929**	**$856,616**

Source: WAPA 2023

Revenue from the Hoover Powerplant customer contracts is set each year. However, impacts from decreases in generation and capacity are still felt. When generation and capacity are reduced or halt, the impacts on hydropower value are still substantial. Typical and wet hydrologic scenarios result in consistent total hydropower value through the 3 operating years. In the drier hydrologic scenarios, total hydropower is substantially impacted by the reduction in generation and capacity. The driest scenarios result in elevations below minimum power pool and an associated halt in total hydropower value in operating year 2026. **Table 3-76** shows the annual total hydropower value for Hoover Powerplant under the No Action Alternative.

Table 3-76
No Action Alternative – Hoover Dam Annual Hydropower Value (Thousands of Dollars)

	Minimum	10th Percentile	Median	90th Percentile	Maximum
2024	$298,158	$337,938	$374,521	$420,232	$464,841
2025	$92,615	$287,641	$360,349	$413,867	$482,993
2026	$0	$106,915	$342,954	$403,017	$497,688
Total	**$390,773**	**$732,494**	**$1,077,824**	**$1,237,116**	**$1,445,522**

Source: Reclamation 2023g

Revenue from the combined Parker and Davis Powerplants' customer contracts are set each year, and impacts from decreases in generation and capacity are much less compared with the Glen Canyon and Hoover Powerplants. The Parker and Davis Powerplants maintain generation and capacity through all hydrologic scenarios, and only minor impacts are felt on the total hydropower value. Only in the driest hydrologic scenarios is there a substantial impact on total hydropower value. **Table 3-77** shows the combined annual total hydropower value for Parker and Davis Powerplants under the No Action Alternative.

Table 3-77
No Action Alternative – Parker-Davis Dams Annual Hydropower Value (Thousands of Dollars)

	Minimum	10th Percentile	Median	90th Percentile	Maximum
2024	$131,824	$141,168	$148,840	$157,040	$169,917
2025	$128,786	$138,204	$145,743	$154,659	$168,019
2026	$94,016	$134,015	$142,136	$150,712	$164,688
Total	**$354,626**	**$413,387**	**$436,719**	**$462,411**	**$502,624**

Source: Reclamation 2023g

Table 3-78 shows the combined total hydropower value across all four powerplants under the No Action Alternative. The trend typically mirrors those from Glen Canyon and Hoover Powerplants, as they exhibit the dominant changes across hydrologic scenarios and operating years. The driest hydrologic scenario results in a substantial decrease in hydropower value each year as Hoover Dam approaches minimum power pool.

Table 3-78
No Action Alternative – Total Annual Economic Value of Electrical Power (Thousands of Dollars)

	Minimum	10th Percentile	Median	90th Percentile	Maximum
2024	$429,982	$548,699	$747,723	$817,264	$890,972
2025	$221,401	$425,845	$736,756	$821,518	$949,634
2026	$94,016	$240,930	$703,903	$808,674	$964,156
Total	**$745,399**	**$1,215,474**	**$2,188,382**	**$2,447,456**	**$2,804,762**

Source: Reclamation 2023g; WAPA 2023

Action Alternative 1

Under Action Alternative 1, power generation and capacity at the Glen Canyon Powerplant would be greater than they would be under the No Action Alternative. This would result in higher hydropower value at the Glen Canyon Powerplant under all hydrologic scenarios.

The total hydropower value would decrease as lake elevations decline at Lake Mead. There would still be the potential for lake elevations at Lake Mead to drop below the minimum power pool, which would result in a halt of generation. Alternative sources of revenue, such as visitor fees to Hoover Dam, would continue; however, these are only targeted to be enough to cover the cost of visitor services.

Revenue from generation at Parker and Davis Powerplants would continue because minimum power pool elevations would be protected. However, changes in releases would impact revenue.

The following tables show the annual total hydropower value at the four analyzed powerplants for operating years 2024–2026. These values represent the minimum, maximum, median, 10th percentile, and 90th percentile of the modeled annual generation values. These values represent dry hydrologic scenarios (minimum, 10th percentile), typical conditions (median), and wet hydrologic scenarios (90th percentile, maximum). These tables help show the trend of hydropower value over the 3 years analyzed.

Table 3-79 shows the values for the annual total hydropower value at the Glen Canyon Powerplant for operating years 2024–2026 under Action Alternative 1. Overall, Action Alternative 1 results in positive hydropower across all hydrologic scenarios. The wetter the conditions, the greater the hydropower value. However, due to a halt in generation and capacity in operating year 2024 under the driest conditions, hydropower value would still fall to zero before climbing up as the reservoir fills back up.

Table 3-79
Action Alternative 1 – Glen Canyon Dam Annual Hydropower Value (Thousands of Dollars)

	Minimum	10th Percentile	Median	90th Percentile	Maximum
2024	$0	$110,465	$168,835	$211,901	$247,455
2025	$64,414	$149,301	$179,706	$235,221	$274,959
2026	$109,581	$161,050	$186,528	$230,152	$279,326
Total	**$173,995**	**$420,816**	**$535,069**	**$677,274**	**$801,740**

Source: WAPA 2023

Table 3-80 shows the values for the annual total hydropower value at the Hoover Powerplant under Action Alternative 1. Like hydropower value at Glen Canyon, the wetter the hydrologic conditions, the greater the total hydropower value. However, Hoover Powerplant is much more susceptible to dropping below minimum power pool under the driest conditions in Action Alternative 1. This would result in a substantial decrease in hydropower value, particularly in operating years 2025 and 2026.

Table 3-80
Action Alternative 1 – Hoover Dam Annual Hydropower Value (Thousands of Dollars)

	Minimum	10th Percentile	Median	90th Percentile	Maximum
2024	$161,441	$301,347	$343,218	$402,867	$455,639
2025	$0	$222,728	$309,008	$408,865	$478,758
2026	$0	$216,743	$327,484	$415,989	$502,464
Total	**$161,441**	**$740,818**	**$979,710**	**$1,227,721**	**$1,436,861**

Source: Reclamation 2023g

Table 3-81 shows the values for the combined annual total hydropower value at the Parker and Davis Powerplants. The Parker and Davis Powerplants are able to continue generation and capacity rates, resulting in continued hydropower value across all hydrologic scenarios. Under the driest conditions, there is a substantial decrease in hydropower value in operating years 2025 and 2026 as releases decline due to continued drought conditions.

Table 3-81
Action Alternative 1 – Parker-Davis Dams Annual Hydropower Value (Thousands of Dollars)

	Minimum	10th Percentile	Median	90th Percentile	Maximum
2024	$122,915	$131,725	$139,856	$150,495	$165,369
2025	$96,389	$110,695	$123,423	$145,582	$163,101
2026	$80,934	$105,553	$125,694	$145,087	$162,947
Total	**$300,238**	**$347,973**	**$388,973**	**$441,164**	**$491,417**

Source: Reclamation 2023g

Table 3-82 shows the total combined annual hydropower value across all four powerplants under Action Alternative 1. There are substantial decreases in total hydropower value between the hydrologic scenarios. However, with the exception of the driest scenarios, the hydropower value remains relatively constant over the 3 operating years. The wetter hydrologic conditions result in a continued increase in hydropower value each year. The driest hydrologic scenarios result in variable hydropower value as Lake Powell and Lake Mead experience a drop below minimum power pool at different points during the 3 operating years.

Table 3-82
Action Alternative 1 – Total Annual Hydropower Value (Thousands of Dollars)

	Minimum	10th Percentile	Median	90th Percentile	Maximum
2024	$284,356	$543,537	$651,909	$765,263	$868,463
2025	$160,803	$482,724	$612,137	$789,668	$916,818
2026	$190,515	$483,346	$639,706	$791,228	$944,737
Total	**$635,674**	**$1,509,607**	**$1,903,752**	**$2,346,159**	**$2,730,018**

Source: Reclamation 2023g; WAPA 2023

Action Alternative 2

Under Action Alternative 2, hydropower value at Glen Canyon Powerplant would be slightly higher compared with Action Alternative 1 due to the potential DROA contributions. The lake reservoir elevation at Lake Powell would maintain continued capacity and generation. This would allow for a continued positive total hydropower value. However, as reservoir elevations at Lake Mead decline, the total hydropower value would also decline. There would be a potential for lake reservoir elevations at Lake Mead to drop below the minimum power pool, which would result in substantial impacts on the total hydropower value. Alternative sources of revenue, such as visitor fees to Hoover Dam, would continue.

Revenue from generation at Parker and Davis Powerplants would continue, as minimum power pool elevations would be protected. However, changes in releases would impact revenue.

The following tables show the annual total hydropower value at the four analyzed powerplants for operating years 2024–2026. These values represent the minimum, maximum, median, 10th percentile, and 90th percentile of the modeled annual generation values. These values represent dry hydrologic scenarios (minimum, 10th percentile), typical conditions (median), and wet hydrologic scenarios (90th percentile, maximum). These tables help show the trend of hydropower value over the 3 years analyzed.

Table 3-83 shows the values for the annual total hydropower value at the Glen Canyon Powerplant for operating years 2024–2026 under Action Alternative 2. The trends are nearly identical to the trends under Action Alternative 1, with slightly higher total hydropower value across all hydrologic scenarios. This is because the potential DROA contributions allow for higher generation and capacity. Even with the potential DROA contributions, the driest hydrologic scenarios would result in lake elevations below minimum power pool in operating year 2024, resulting in a complete halt in total hydropower value.

Table 3-83
Action Alternative 2 – Glen Canyon Dam Annual Hydropower Value (Thousands of Dollars)

	Minimum	10th Percentile	Median	90th Percentile	Maximum
2024	$0	$116,089	$169,325	$211,901	$247,463
2025	$72,260	$153,173	$185,838	$237,871	$276,188
2026	$142,740	$165,527	$199,500	$231,642	$279,346
Total	**$215,000**	**$434,789**	**$554,663**	**$681,414**	**$802,997**

Source: WAPA 2023

Table 3-84 shows the annual totally hydropower value at the Hoover Powerplant under Action Alternative 2. The trends are nearly identical to the trends under Action Alternative 1, with higher total hydropower value across all hydrologic scenarios. This is because the potential DROA contributions allow for higher generation and capacity. Even with the potential DROA contributions, the driest hydrologic scenarios would result in lake elevations below minimum power pool in operating years 2025 and 2026, resulting in a substantial decline in total hydropower value.

Table 3-84
Action Alternative 2 – Hoover Dams Annual Hydropower Value (Thousands of Dollars)

	Minimum	10th Percentile	Median	90th Percentile	Maximum
2024	$197,137	$299,197	$338,874	$403,903	$458,012
2025	$0	$232,500	$307,576	$410,279	$460,406
2026	$0	$222,472	$326,467	$417,077	$491,800
Total	**$197,137**	**$754,169**	**$972,917**	**$1,231,259**	**$1,410,218**

Source: Reclamation 2023g

Table 3-85 shows the combined annual total hydropower value at the Parker and Davis Powerplants under Action Alternative 2. The trends are nearly identical to the trends under Action Alternative 1, with slightly higher total hydropower value across all hydrologic scenarios; this is because the potential DROA contributions allow for higher generation.

Table 3-85
Action Alternative 2 – Parker-Davis Dams Annual Hydropower Value (Thousands of Dollars)

	Minimum	10th Percentile	Median	90th Percentile	Maximum
2024	$118,745	$127,576	$135,810	$149,152	$163,242
2025	$95,399	$107,661	$118,740	$143,064	$158,654
2026	$87,154	$102,559	$121,253	$143,653	$158,691
Total	**$301,298**	**$337,796**	**$375,803**	**$435,869**	**$480,587**

Source: Reclamation 2023g

Table 3-86 shows the values for total combined annual hydropower value at all four powerplants under Action Alternative 2. The trends are nearly identical to the trends under Action Alternative 1, with slightly higher total hydropower value across all hydrologic scenarios; this is because the potential DROA contributions allow for greater generation and capacity.

Table 3-86
Action Alternative 2 – Total Annual Hydropower Value (Thousands of Dollars)

	Minimum	10th Percentile	Median	90th Percentile	Maximum
2024	$315,882	$542,862	$644,009	$764,956	$868,717
2025	$167,659	$493,334	$612,154	$791,214	$895,248
2026	$229,894	$490,558	$647,220	$792,372	$929,837
Total	**$713,435**	**$1,526,754**	**$1,903,383**	**$2,348,542**	**$2,693,802**

Source: Reclamation 2023g; WAPA 2023

Cumulative Effects

The potential operational changes included in the Glen Canyon Dam/Smallmouth Bass flow options would result in a substantial decrease in power generation, capacity, and, therefore, total hydropower value at the Glen Canyon Powerplant. The reduction in generation would be offset by the purchase of replacement power. This purchase of replacement power could further impact the total hydropower value.

The additional revenue from the action alternatives, particularly under dry hydrologic scenarios, could help offset this reduction in total hydropower value. The EA would have minor cumulative impacts under the No Action Alternative and dry hydrologic conditions because lake elevations would drop below minimum power pool, resulting in a halt of revenue at Glen Canyon Dam. The EA would not impact operations at the Lower Basin powerplants. Therefore, there would be no additional impacts on the total hydropower value at other powerplants.

Issue 4: How would changes in total hydropower value impact the various power funds?

The various power funds are operated in different manners and, therefore, are impacted differently based on the alternative and the associated revenue. The Basin Fund receives revenue from customers based on contracts and operations at the Glen Canyon Powerplant. The Development Fund receives revenue from customers based on contracts and operations at the Hoover, Parker, and Davis Powerplants. The Dam Fund and Parker-Davis Account receive a set revenue directly from customers based on contracts. Implementation of the various alternatives will likely result in more variation in the power funds and could lead to additional actions, such as power rate adjustments, rate surcharges, or reductions to customer allocations, to respond to shortfalls in revenue under dry conditions.

The following qualitative analysis is based on revenue and total hydropower value modeling associated with each analyzed powerplant under each action alternative. Quantitative impacts are difficult to accurately model.

Summary

Lake Powell has the highest chance to drop below minimum power pool under the No Action Alternative. Loss of generation would result in multiple severe impacts, including the loss of revenues necessary for the Basin Fund to support critical operations at WAPA and Reclamation. Compared with the No Action Alternative, both action alternatives would result in increased revenue and total hydropower value at the Glen Canyon Powerplant and, therefore, increased financial resources for the Basin Fund. The Basin Fund would have the greatest amount of financial resources under the wet hydrologic scenarios.

Compared with the No Action Alternative, Action Alternatives 1 and 2 would decrease total hydropower value at Hoover Dam, resulting in a decrease in financial resources for the Development Fund. Under Action Alternatives 1 and 2, the Parker and Davis Powerplants would continue to have positive total hydropower value and would continue to contribute to the Development Fund. The No Action Alternative would allow for greater hydropower value at the Hoover, Parker, and Davis Powerplants and would result in the least amount of impacts on the Development Fund.

The Dam Fund and Parker-Davis Account would receive the same amount of revenue from customers under all three alternatives and would only be impacted by operations and maintenance costs. It can be assumed that the impacts under the action alternatives would be greater than the impacts under the No Action Alternative due to the decreased releases and total hydropower value.

No Action Alternative

Under the No Action Alternative, the total hydropower value would decrease at the Glen Canyon Powerplant. Lake reservoir elevations at Lake Powell have the potential to drop below the minimum power pool and halt generation and total hydropower value completely. This is particularly true under dry hydrologic scenarios. Any large reduction or halt in total hydropower value would have severe impacts on the Basin Fund. Under the wet hydrologic conditions, total hydropower value would remain above zero, but it would still be lower compared with under the action alternatives.

The Development Fund would remain relatively unimpacted under wet hydrologic scenarios under the No Action Alternative. However, during dry hydrologic scenarios, total hydropower value would be severely impacted, particularly later in the project timeline, and could result in severe impacts on the Development Fund.

The Dam Fund and Parker-Davis Account receive a set amount of revenue directly from customers and would only see minor impacts from the No Action Alternative. Reduced generation and capacity at the Hoover Powerplant would have slight impacts on the Dam Fund. The lake reservoir elevation protections at Lake Havasu and Lake Mohave allow for continued generation, capacity, and hydropower value at the Parker and Davis Powerplants. There would be a slight decrease in releases, which would impact the generation and total hydropower value; this would result in minor impacts on the Parker-Davis Account.

Action Alternative 1

Under Action Alternative 1, the total hydropower value would increase at the Glen Canyon Powerplant compared with under the No Action Alternative. Lake reservoir elevation protection at Lake Powell would result in continued operations above minimum power pool under all but the driest hydrologic scenarios. This would result in additional financial resources for the Basin Fund. The driest hydrologic scenario would result in impacts on the Basin Fund, particularly in operating year 2024 when elevations could start below minimum power pool, but the fund would recover in operating years 2025 and 2026.

Under Action Alternative 1, Lake Mead could drop below minimum power pool in the drier hydrologic scenarios, resulting in substantial impacts on the Development Fund. Even under typical hydrologic scenarios, Lake Mead's elevation would be reduced, resulting in impacts on total hydropower value and the associated contributions to the Development Fund. These impacts would be slightly offset by continued total hydropower value at the Parker and Davis Powerplants. However, the Parker and Davis Powerplants would also see slight impacts on the total hydropower value and the associated contributions to the Development Fund. Overall, Action Alternative 1 would result in greater impacts on the Development Fund when compared with the No Action Alternative.

The Dam Fund and Parker-Davis Account receive a set amount of revenue directly from customers and would only see minor impacts from Action Alternative 1. Reduced total hydropower value at the Hoover Powerplant would have impacts on the Dam Fund. The lake reservoir elevation protections at Lake Havasu and Lake Mohave allow for continued generation, capacity, and hydropower value at the Parker and Davis Powerplants. There would be a slight decrease in releases, which would impact the generation and total hydropower value; this would result in minor impacts on the Parker-Davis Account.

Action Alternative 2

Under Action Alternative 2, impacts on the Basin Fund would be very similar compared with Action Alternative 1, but with slightly less impacts on the Basin Fund. This is because the potential DROA contributions would help total hydropower value at Glen Canyon Dam.

Impacts on the Development Fund would be very similar to impacts under Action Alternative 1; however, there would be slightly less impacts on the Development Fund because the potential DROA contributions would help total hydropower value at Hoover Dam.

Impacts on the Dam Fund and Parker-Davis Account would remain minor, which would be similar to both the No Action Alternative and Action Alternative 1. There would be a very slight change in impacts compared with Action Alternative 1, as the potential DROA contributions would only slightly help total hydropower value.

Cumulative Effects

The potential operational changes included in Glen Canyon Dam would result in a substantial decrease in total hydropower value at the Glen Canyon Powerplant and a decrease in the associated contributions to the Basin Fund. The additional total hydropower value at Glen Canyon Powerplant from the action alternatives could help offset this decrease in revenue. Overall, the Basin Fund would see a decrease in revenue compared with recent annual values. The EA would not impact total hydropower value at the Lower Basin powerplants. Therefore, there would be no additional impacts on other Lower Basin power funds.

Issue 5: How would impacts on the basin funds affect other governmental programs?

The various power funds provide funding for multiple governmental programs in the Upper and Lower Colorado Basin, including the Upper Colorado River Endangered Fish Recovery Program, the Colorado River Basin Salinity Control Program, the Glen Canyon Adaptive Management Program, the Central Arizona Project, the Lower Colorado River Multi-Species Conservation Program, and other projects, as directed by the Arizona Water Rights Settlements Act. The programs and projects would be directly impacted by any changes in financial reserves within the power funds. Some programs are able to receive flexible funding from both upper and lower power funds, which could help reduce impacts.

These impacts are difficult to model accurately; therefore, a qualitative analysis has been included based on total hydropower value modeling and impacts on the power funds, as outlined in Issue 4.

Summary

Compared with under the No Action Alternative, available funding in the Basin Fund would be greater under the action alternatives. These additional financial reserves would help provide funding for the government programs that rely on funding from the Basin Fund. Impacts on the Development Fund and Dam Fund are harder to analyze but would most likely be negatively impacted by the action alternatives under higher hydrologic scenarios.

No Action Alternative

Under the No Action Alternative, the Basin Fund and Development Fund would see significant impacts due to reduced total hydropower value from power generation and capacity, particularly in low hydrology scenarios. The Basin Fund provides funding for the Upper Colorado River Endangered Fish Recovery Program, the Colorado River Basin Salinity Control Program, and the Glen Canyon Adaptive Management Program. All three programs could see reductions in funding from the Basin Fund. The Development Fund helps fund the Lower Colorado River Multi-Species Conservation Program, the Colorado River Basin Salinity Control Program, the CAP, and projects as directed by the Arizona Water Rights Settlements Act. All these programs could see reductions in funding and repayment from the Development Fund.

The Dam Fund and Parker-Davis Account would be less impacted under the No Action Alternative compared with the Basin and Development Funds. However, there would be slight impacts on total hydropower value and therefore contributions to the Dam Fund and the Parker-Davis Account. The Dam Fund and Parker-Davis Account help fund the Lower Colorado River Multi-Species Conservation Program, the Colorado River Basin Salinity Control Program, the CAP, and projects as directed by the Arizona Water Rights Settlements Act. All these programs could see slight reductions in funding and repayment from the Dam Fund and Parker-Davis Account.

Action Alternative 1

Under Action Alternative 1, the Basin Fund would see minor impacts due to the decrease in reservoir elevations but continuation of generation, capacity, and total hydropower value at Glen Canyon Powerplant. Funding for the Upper Colorado River Endangered Fish Recovery Program, the Colorado River Basin Salinity Control Program, and the Glen Canyon Adaptive Management Program would experience only slight impacts. These impacts would be substantially less compared with the No Action Alternative.

The Development Fund would potentially experience significant impacts on available funding. Available funding would decrease as the reservoir elevation and releases dropped; if Lake Mead dropped below the minimum power pool, impacts could be severe. This would result in a decrease in total hydropower value and would mean funding would be reduced for the Lower Colorado River Multi-Species Conservation Program, the Colorado River Basin Salinity Control Program, the CAP, and other projects, as directed by the Arizona Water Rights Settlements Act. Impacts on these programs could be worse compared with the No Action Alternative.

Under Action Alternative 1, the Dam Fund and Parker-Davis Account would be less impacted compared with the Basin and Development Funds. However, there would be slight impacts on total hydropower value and therefore contributions to the Dam Fund and Parker-Davis Account. The Dam Fund and Parker-Davis Account help fund the Lower Colorado River Multi-Species Conservation Program, the Colorado River Basin Salinity Control Program, the CAP, and projects as directed by the Arizona Water Rights Settlements Act. All these programs could experience slight reductions in funding and repayment from the Dam Fund and Parker-Davis Account.

Action Alternative 2

Under Action Alternative 2, impacts on the various power funds would be very similar to those described under Action Alternative 1 and would, therefore, have similar impacts on any governmental programs listed above. With the potential DROA contributions, there would be slightly greater total hydropower value and slightly less impacts on the power funds. This would result in slightly more funds being available for governmental programs. These impacts would be minor compared with Action Alternative 1.

Cumulative Effects

The potential operational changes included in the Glen Canyon Dam/Smallmouth Bass flow options would result in a substantial decrease in funds available in the Basin Fund and, therefore, a substantial decrease in available funds for the governmental programs aided by the Basin Fund. The additional total hydropower value from the action alternatives could help offset this decrease in funds. There would be no additional impacts on the Lower Basin funds and the governmental programs that receive funding from them.

Issue 5: How would impacts on the power generation affect ancillary services?

Ancillary services, such as regulation and reserve, require certain lake reservoir elevations and releases so that generation and capacity can continue at a rate that allows for up and down regulation along with the necessary reserves. Ancillary services see only minor impacts until elevations and releases drop near or below minimum power pool. If penstock releases dropped below those levels or stopped completely, these ancillary services would be negatively impacted.

At Glen Canyon Dam, flows are required to be approximately 1,000–2,000 cfs above the minimum flows, as outlined in the LTEMP, for ancillary services to continue. The Glen Canyon Powerplant typically holds approximately 40 MW in regulation.

Hoover Dam ancillary services would be proportionately impacted as lake levels and projected energy generation drop. Flexibility of release and the ability to leverage downstream storage at Davis and Parker Dams creates significant opportunities to utilize ancillaries such as regulation and reserves from Hoover Dam. Parker and Davis Dams would have minor impacts on ancillary services.

Summary

Ancillary services at all four analyzed dams would be impacted under the No Action Alternative as reservoir elevations approached minimum power pool. In low hydrologic scenarios, under the No Action Alternative, reservoir elevations at Lake Powell and Lake Mead would drop below the minimum power pool, resulting in a complete halt of generation, capacity, and ancillary services. Ancillary services at Glen Canyon Dam would be significantly more impacted under the No Action Alternative compared with either of the action alternatives. Ancillary services at the Hoover Powerplant would be negatively impacted under the action alternatives compared with the No Action Alternative. Parker-Davis Powerplants would have minor impacts on ancillary services due to the lake reservoir elevation protections.

No Action Alternative

Under the No Action Alternative, penstock releases from Glen Canyon, Hoover, Parker, and Davis Dams would continue as outlined in the 2007 FEIS. Under the drier hydrologic scenarios, this would result in reservoir elevations dropping below the minimum power pool at Lake Powell and Lake Mead. This would result in a complete halt in ancillary services such as regulation and reserve. It may or may not be feasible for WAPA to find other facilities to make up for the decrease in regulation and reserve.

The Parker and Davis Powerplants would be able to continue with ancillary services due to the lake reservoir elevation protections. However, under the driest hydrologic conditions, these lake elevations and releases can drop to the point where ancillary services may be impacted.

Under the wet hydrologic scenarios, ancillary services at all four analyzed powerplants would be able to continue.

Action Alternative 1

Overall, the Glen Canyon Powerplant ancillary services would be much less impacted under Action Alternative 1 compared with the No Action Alternative. Under Action Alternative 1, lake reservoir elevations at Lake Powell would be protected, resulting in continued power generation and capacity. Ancillary services at the Glen Canyon Powerplant would continue unimpacted as long as minimum flows remained at approximately 1,000–2,000 cfs above minimum LTEMP regulations. If releases dropped below these levels, ancillary services would be negatively impacted. If this occurs, it may or may not be feasible for WAPA to find other facilities to make up for the decrease in regulation and reserve.

Under the driest hydrologic conditions, Lake Mead reservoir elevations would drop below minimum power pool. This would result in a halt of ancillary services at the Hoover Powerplant. As flows decrease toward the minimum power pool, regulation and reserves at Hoover Dam would be negatively impacted. If reservoir elevations were to drop below power pool, ancillary services would cease entirely. If this were to occur, it may or may not be feasible for WAPA to find other facilities to make up for the decrease in regulation and reserve.

The Parker and Davis Powerplants would be able to continue with ancillary services due to the lake reservoir elevation protections. However, under the driest hydrologic conditions, these lake elevations and releases can drop to the point where ancillary services may be impacted.

Under the wet hydrologic scenarios, ancillary services at all four analyzed powerplants would be able to continue.

Action Alternative 2

Under Action Alternative 2, impacts on ancillary services would be very similar to those described under Action Alternative 1. However, if potential DROA contributions are planned during any year, the additional water would result in higher reservoir elevations, higher releases, and less impacts on ancillary services.

Cumulative Effects
The potential operational changes included in the Glen Canyon Dam/Smallmouth Bass flow options could have substantial negative impacts on ancillary services if reservoir elevations drop toward minimum power pool and releases drop below LTEMP minimums flows. Additional water would be released through the river outlet works, resulting in less generation and potentially negative impacts on regulation and reserve. The EA would not impact operations at the Lower Basin powerplants. Therefore, the EA would not result in any additional impacts on ancillary services at Hoover, Parker, or Davis Dams.

3.16 Socioeconomics

This section provides an overview of socioeconomic conditions in the study area. The baseline information and analysis tier off the 2007 FEIS (Reclamation 2007). In the 2007 FEIS consumptive use was apportioned between the Upper and Lower Basins of the Colorado River and then further apportioned to individual states and entities based on a range of anticipated shortage amounts. The risk of continued drought and reservoir elevations declining below those considered likely in the 2007 FEIS requires consideration of updates to the 2007 Interim Guidelines to protect the reservoir elevations of Lake Powell and Lake Mead, as analyzed in this SEIS.

Information is provided in this document to update the analysis, as appropriate, to reflect overall changes in social and economic conditions in the Basin with the potential to be impacted by management decisions and to reflect updated information on the water use levels for key use sectors and associated economic contributions. The potentially affected socioeconomic issues addressed in this section include:

- Agricultural production and the resulting changes in employment, income, and tax revenues
- Municipal and industrial uses of water and the resulting changes in economic activity
- Reservoir-related and river-related recreation and the resulting changes in employment, income, and consumer surplus value

Financial impacts from changes to hydropower availability and power costs are addressed in **Section 3.15**, Electrical Power Resources.

3.16.1 Affected Environment

Socioeconomic Study Area
The study area for this SEIS is the same as that described in the 2007 FEIS; this is due to the potential for additional water shortages throughout the lower Colorado River Basin states.

The Arizona study area consists of Coconino, La Paz, Maricopa, Mohave, Pima, Pinal, and Yuma Counties (counties either directly adjacent to Lake Powell, Lake Mead, or the Colorado River, or counties in which shortages would likely occur). The counties in which measurable shortages could potentially occur, resulting in reductions in agricultural production or reduced municipal and industrial deliveries, are La Paz, Maricopa, Mohave, Pinal, Pima, and Yuma Counties. Although

Coconino County would not experience a water shortage attributable to the proposed alternatives, it is included in the study area because it is adjacent to the Colorado River and may be affected by changes in recreation-related economic activity as a result of changes in river flows.

The California study area consists of Imperial, Los Angeles, Orange, Riverside, San Bernardino, and San Diego Counties. These counties were selected because they are either directly adjacent to the lower Colorado River, or they are within the MWD service area. Although Ventura County is also in MWD's service area, it does not receive any water from the Colorado River; therefore, it is not included in the study area.

The Nevada study area consists of Clark County. The study area was limited to Clark County because it is adjacent to Lake Mead and encompasses the SNWA's service area. Shortages in Nevada would be limited to the SNWA's service area.

The Utah study area consists of Garfield, Kane, and San Juan Counties. Although Utah will not experience shortages under any alternative, changes in storage at Lake Powell could result in changes in recreation-related expenditures made in these counties.

Baseline Economic Conditions

This section provides an overview of baseline economic conditions related to Colorado River water use with the potential to be impacted by water shortages. For additional details, refer to the 2007 FEIS.

Arizona

Population

Population is a driver of demand for consumptive water use, particularly for municipal water. Populations throughout the western US have followed increasing trends over the past decade. With the exception of La Paz County (loss of 18 percent), Arizona study area counties follow this trend, with the biggest increase in Pinal County (27.7 percent). **Table 3-87**, below, provides an overview.

Employment

Table 3-88, below, provides an overview for employment by sector for the counties in the study area within Arizona. Comparisons are made where applicable 2004 data are provided in the 2007 FEIS. Full- and part-time employment in Arizona totaled 4,055,932 jobs in 2021, an increase of approximately 1,008,389 jobs from 2004 levels. Farm employment totaled 29,309 jobs in 2021 and accounted for 0.7 percent of total employment in the state; this is the same percentage as in 2004.

Employment in the study area counties represents approximately 93 percent of total employment in Arizona. Employment in the agricultural sector in the seven counties totaled 16,349 jobs in 2021 and represented less than 1 percent of total employment in the study area counties (Bureau of Economic Analysis 2023a).

Table 3-87
Arizona Population 2010–2021

	Coconino County	La Paz County	Maricopa County	Mohave County	Pima County	Pinal County	Yuma County	Arizona
Population 2010	131,824	20,549	3,751,410	199,177	964,462	329,297	190,526	6,246,816
Population 2021	144,942	16,845	4,367,186	211,274	1,035,063	420,625	202,944	7,079,203
Percent Change 2010–2021	10.0	-18.0	16.4	6.1	7.3	27.7	6.5	13.3

Source: Headwaters Economics Economic Profile System 2023

Table 3-88
Arizona Employment by Industry (2021)

	Coconino County	La Paz County	Maricopa County	Mohave County	Pima County	Pinal County	Yuma County	Arizona
Total employment	84,555	7,801	2,860,955	78,406	537,770	109,679	91,280	4,055,932
Wage and salary employment	64,693	6,259	2,202,144	56,716	404,217	68,886	73,885	3,076,770
Proprietors' employment	19,862	1,551	658,811	21,690	130,553	40,793	17,395	979,162
Farm employment (number and percentage of total employment)	2,117	458	6,453	520	1,161	2,287	3,353	29,309
	2.5%	5.9%	0.2%	0.7%	0.2%	2.1%	19.1%	0.7%
Non-farm employment (number and percentage of total employment)	82,438	7,352	2,854,520	77,886	533,609	107,392	87,927	4,026,623
	97.5%	94.1%	99.8%	99.3%	99.8%	97.9%	80.9%	99.3%

	Coconino County	La Paz County	Maricopa County	Mohave County	Pima County	Pinal County	Yuma County	Arizona
Employment by Industry (Number and Percentage of Total Employment)								
Forestry, fishing, and related	266	D	2,553	D	490	572	7,157	13,832
	0.3%	D	0.1%	D	0.1%	0.5%	7.8%	0.3%
Mining, quarrying, and oil and gas extraction	142	59	6,453	445	3,300	1,256	88	17,894
	0.2%	0.8%	0.2%	0.6%	0.6%	1.1%	0.1%	0.4%
Utilities	196	21	8,309	405	2,095	332	165	12,720
	0.2%	0.8%	0.3%	0.5%	0.4%	0.3%	0.2%	0.3%
Construction	4,034	184	184,242	6,557	28,062	6,283	4,920	253,184
	4.8%	2.4%	6.4%	8.4%	5.2%	5.7%	5.4%	6.2%
Manufacturing	3,661	257	141,468	3,401	29,734	5446	3,044	195,722
	4.3%	3.3%	4.9%	4.3%	5.6%	5.0%	2.1%	4.8%
Wholesale trade	1,204	130	92,909	1,691	8,857	1,944	1,925	115,142
	1.4%	1.7%	3.2%	2.2%	1.7%	1.8%	2.1%	2.8%
Retail trade	8,669	1,673	282,511	12,180	52,464	14,072	9,909	413,565
	10.3%	21.4%	9.9%	15.5%	9.8%	12.8%	10.9%	10.2%
Transportation and warehousing	2,384	193	169,998	2,960	28,933	6,359	3,220	224,294
	2.8%	2.5%	5.9%	3.8%	5.4%	5.8%	3.5%	5.5%
Information	645	87	48,230	656	6,653	872	482	59,769
	0.8%	1.1%	1.7%	0.8%	1.2%	0.8%	0.5%	1.5%
Finance and insurance	1,962	D	243,962	2,808	24,871	4,315	3,692	290,236
	2.3%	D	8.5%	3.6%	4.7%	3.9%	4.0%	7.2%
Real estate rental and leasing	4,147	D	172,770	4,821	28,896	5,946	3,143	234,832
	4.9%	D	7.3%	6.1%	5.4%	5.4%	3.4%	5.8%
Professional, scientific, and technical services	3,735	D	39,192	2,909	33,399	5,017	3,709	269,961
	4.4%	D	1.4%	3.7%	6.2%	4.6%	4.1%	6.7%
Management of companies and enterprises	468	D	244,023	222	2,726	434	353	44,165
	0.6%	D	8.5%	0.3%	0.5%	0.4%	0.4%	1.1%
Administrative, support, and waste management	2,626	150	65,739	4,211	37,001	7,968	6,191	313,831
	3.1%	1.9%	2.3%	5.4%	6.9%	7.3%	6.8%	7.7%

	Coconino County	La Paz County	Maricopa County	Mohave County	Pima County	Pinal County	Yuma County	Arizona
Educational services	1,075	D	325,464	805	9,300	2,205	697	85,070
	1.3%	D	11.4%	1.0%	1.7%	2.0%	0.8%	2.1%
Health care and social assistance	9,627	D	56,772	9,491	70,081	7,241	9,221	459,980
	11.4%	D	2.0%	12.1%	13.1%	6.6%	10.1%	11.3%
Arts, entertainment, and recreation	3,083	D	56,772	D	11,588	2,676	683	81,541
	3.6%	D	2.0%	D	2.2%	2.4%	0.7%	2.0%
Accommodation and food services	13,716	D	193,676	9,572	38,277	7,385	7,055	293,749
	16.2%	D	6.8%	12.2%	7.2%	6.7%	7.7%	7.2%
Other services	3,695	D	135,811	5,109	29,315	6,872	4,148	200,894
	4.4%	D	4.7%	6.5%	5.5%	6.3%	4.5%	5.0%
Government and government enterprises	17,103	2,022	234,204	8,352	87,567	20,197	18,125	446,242
	20.2%	25.9%	8.2%	10.7%	16.4%	18.4%	19.9%	11.0%

Source: Bureau of Economic Analysis 2023a

(D) = Not shown to avoid disclosure of confidential information; estimates are included in higher-level totals.

Personal Income

Total personal income in Arizona totaled just over $403.4 billion in 2021, compared with $227.9 billion in 2004 (adjusted to 2021$). Likewise, per capita income increased from approximately $40,960 in 2004 (adjusted to 2021$) to approximately $55,487 in 2021; this is a 35 percent increase (see **Table 3-89**; Bureau of Economic Analysis 2023b).

Among the seven counties, average per capita income ranged from a low of approximately $41,331 per year in La Paz County to a high of $59,759 per year in Maricopa County. Only Maricopa and Coconino Counties had per capita income above the state of Arizona average ($55,487). The total personal income generated in the seven counties represents around 92 percent of the state total (Bureau of Economic Analysis 2023b).

Table 3-89
Arizona Personal Income and Earnings (2021)

	Coconino County	La Paz County	Maricopa County	Mohave County	Pima County	Pinal County	Yuma County	Arizona
Personal income ($1,000s)	$8,255,426	$819,303	$268,713,717	$8,997,444	$55,696,681	$19,687,597	$9,169,548	$403,739,312
Per capita personal income	$56,914	$49,933	$59,759	$41,331	$52,942	$43,793	$44,299	$55,487
Earnings by place of work	$4,633,046	$365,268	$192,958,723	$3,807,031	$31,731,662	$5,182,726	$5,472,861	$258,941,005
Wages and salaries	$3,154,528	$281,717	$146,954,704	$2,626,349	$22,652,731	$3,512,696	$3,732,656	$193,197,269
Supplements to wages and salaries	$810,341	$72,577	$27,989,246	$591,791	$5,328,512	$870,907	$1,013,969	$39,417,203
Proprietors' income	$668,177	$10,974	$18,014,773	$588,891	$3,750,419	$799,123	$726,236	$26,326,533

Source: Bureau of Economic Analysis 2023b

Agriculture

Approximately 36 percent of Arizona's land area in 2018 was used for agricultural purposes (either crop or livestock production). According to an agricultural economic profile on Arizona counties for 2017[21] (Duval et al. 2020), the total market value of agricultural production in Arizona contributed $23.3 billion to Arizona's economy. Direct contributions from the sale of farm products, the manufacture of crop inputs, and crop processing, marketing, and distribution accounted for $14.8 billion, with an additional $8.5 billion coming indirectly from economic activity generated as a result of agricultural income (Lahmers and Edan 2018). The types of crops and amount of water used for agriculture and the role of agriculture in county economics vary across the state. The top agricultural industries by employment include citrus, hay farming, cotton farming, and crop harvesting (Lahmers and Edan 2018).

[21] The 2017 agricultural census from the National Agricultural Statistics Service (used in reports developed by Duval et al. 2020) provides the most recent available data on the market value of agricultural production at the county level. The next agricultural census data release is due in the spring/summer 2024.

Central and southwestern Arizona have long been the center of agricultural production in Arizona; central and southwestern Arizona farms contribute the largest share of agricultural production in terms of sales values. In 2017, the market value of agricultural production occurring within the Arizona study area accounted for nearly 62 percent of the statewide on-farm agricultural production value and 0.41 percent of Arizona total gross domestic product (GDP). In 2017, production values ranged from a low of approximately $17.1 million in La Paz County to a high of $1,200 million in Yuma County (Duval et al. 2020). **Table 3-90** presents a summary of the market value of on-farm agricultural production with respect to county and state GDP.

In the western US, while agriculture represents a relatively small share of the US production, it requires large amounts of irrigation water. The most water-intensive crops include food, feed, and fiber production. In Arizona, irrigated agriculture accounts for about 75 percent of the state's water use; more than 50 percent of this is from surface waters. According to the 2007 FEIS, urbanization of agricultural lands and heavy investment by the irrigated agricultural industry in conservation measures both on farms and in the delivery system percentage have resulted in a reduction in the percentage (from as high as 90 percent) of water used by agricultural irrigation. Improvements in irrigation technology; voluntary fallowing programs that compensate farmers who reduce water consumption; and utilization of more effective irrigation strategies, such as changes to irrigation timing, have resulted in a reduction in agriculture's share of water consumption (Lahmers and Edan 2018).

Table 3-90
Market Value of On-Farm Agricultural Production in Arizona Study Area (2017)[1]

Area	Market Value of Production ($1,000,000)	Percentage of County GDP	Percentage of Arizona GDP
Maricopa County	89.4	0.04	0.03
Pima County	64.5	0.14	0.02
Pinal County	28.1	0.37	0.01
Total within CAP Counties	**182.0**	**0.06**	**0.05**
La Paz County	17.1	2.55	0.00
Mohave County	27	0.47	0.01
Yuma County	1,200	14.46	0.34
Total within Arizona Study Area[2]	**1,426.1**	**0.45**	**0.41**

Source: Duval et al. 2020

Note: CAP values are aggregated values of Maricopa, Pima, and Pinal Counties.

[1] The 2017 agricultural census from the National Agricultural Statistics Service (used in reports developed by Duval et al. 2020) provides the most recent available data on the market value of agricultural production at the county level. The next agricultural census data release is due in the spring/summer 2024.

[2] Coconino County is included in the Arizona study area due to the potential for recreation-related impacts, but it does not receive Colorado River irrigation water and is excluded from this table.

Agricultural lands receiving water for irrigation from the CAP are generally within Pinal, Maricopa, and Pima Counties. The three counties account for approximately 50 percent of statewide irrigated and harvested cropland (USDA 2019a). These three counties also account for approximately 70 precent of Arizona's harvested cotton acreage, 50 percent of the state's hay crops, and approximately 44 percent of irrigated wheat cultivation (USDA 2019a).

Agricultural resources in western Arizona are primarily along the Colorado River in Mohave, La Paz, and Yuma Counties and along the Gila River Valley in Yuma County. These three western Arizona counties account for approximately 54 percent of statewide irrigated wheat cultivation, 76 percent of vegetable crops, and 36 percent of hay crops (USDA 2019a). Yuma County alone produces 75 percent of the state's total vegetable crops. **Table 3-91** provides a summary of county-wide irrigated agricultural lands within the Arizona study area.

Table 3-91
Irrigated Acres of Harvested Agriculture in the Arizona Study Area (2017)[1]

Area	Irrigated Cropland (Acres)	Total Cropland (Acres)	Percent Irrigated Cropland
Maricopa County	177,975	187,467	95
Pima County	29,154	29,192	100*
Pinal County	231,092	235,185	98
Total within CAP Counties	**438,221**	**451,844**	**97**
La Paz County	(D)	96,204	(D)
Mohave County	20,713	22,002	94
Yuma County	181,244	193,823	94
Total Arizona[2]	**876,272**	**915,647**	**96**

Source: USDA 2019a
Note: CAP values are aggregated values of Maricopa, Pima, and Pinal Counties. Totals for the Arizona study area are not presented due to a lack of data for some counties.
* Percent irrigated cropland is 99.9 percent of total cropland in Pima County.
(D) = data determined too sensitive to disclose.
[1] The 2017 agricultural census from the National Agricultural Statistics Service (used in reports developed by Duval et al. 2020) provides the most recent available data on the market value of agricultural production at the county level. The next agricultural census data release is due in the spring/summer 2024.
[2] Coconino County is included in the Arizona study area due to the potential for recreation-related impacts, but it does not receive Colorado River irrigation water and is excluded from this table.

Table 3-92 shows changes between 2012 and 2017 in acres of irrigated cropland compared with changes to acres of total cropland in each county. In general, there is a correlation between percent change in irrigated cropland and percent change in total cropland within the CAP counties. Changes can be due to changing cropping patterns or technological and farming strategy modifications that contribute to expansion of nonirrigated agriculture in Arizona, where irrigation would otherwise be essential. For example, an increase in total Yuma County cropland between 2012 and 2017 was due to expansion of nonirrigated cropland.

Table 3-92
Irrigation Trend for Harvested Agriculture in the Arizona Study Area (2012–2017)[1]

Area	Percent Change in Irrigated Cropland	Percent Change in Total Cropland
Maricopa County	-6.6	-4.9
Pima County	1.7	1.6
Pinal County	4.1	3.6
Total within CAP Counties	**-0.7**	**-0.2**
La Paz County	(D)	-7.6
Mohave County	(D)	(D)
Yuma County	0.0	5.1
Total Arizona[2]	**2.6**	**2.9**

Source: USDA 2019a

Note: CAP values are aggregated values of Maricopa, Pima, and Pinal Counties. Totals for the Arizona study area are not presented due to a lack of data for some counties.

(D) = data determined too sensitive to disclose.

[1] The 2017 agricultural census from the National Agricultural Statistics Service (used in reports developed by Duval et al. 2020) provides the most recent available data on the market value of agricultural production at the county level. The next agricultural census data release is due in the spring/summer 2024.

[2] Coconino County is included in the Arizona study area due to the potential for recreation-related impacts, but it does not receive Colorado River irrigation water and is excluded from this table.

The proportion of irrigation water that comes from all surface water resources in each county is shown in **Table 3-93**. In general, there is a correlation between the trend in the change of the percentage of irrigation water that comes from surface waters and the trend in total acre-feet of surface water used for irrigating croplands. However, all or part of the change in volume of irrigation water from surface water resources may be due to changes in contributions from groundwater. In Mohave County, although the percentage of irrigated cropland sourced from surface waters decreased from 75 percent in 2010 to 56 percent by 2015, the total acres of irrigated cropland receiving surface water increased by 14 percent. Between 2010 and 2015, the total water usage of Mohave County, which includes groundwater sources in addition to surface waters, increased more rapidly than the increase in acre-feet of water from surface waters alone. The proportion from surface water's contribution decreased.

Table 3-93
Percent Irrigated Water from Surface Water Sources

Area	Percent Agricultural Water from Surface Waters (2010)	Percent Agricultural Water from Surface Waters (2015)[1]	Percent Change in Acre-Feet of Irrigation Water from Surface Waters (2010–2015)
Maricopa County	27	21	-10
Pima County	33	39	9
Pinal County	76	62	-28
Total within CAP Counties	**51**	**39**	**-23**

Area	Percent Agricultural Water from Surface Waters (2010)	Percent Agricultural Water from Surface Waters (2015)[1]	Percent Change in Acre-Feet of Irrigation Water from Surface Waters (2010–2015)
La Paz County	92	87	-13
Mohave County	75	56	-14
Yuma County	85	90	2
Total within Arizona Study Area[2]	**70**	**61**	**-11**
Total Arizona	**64**	**57**	**-11**

Source: USGS 2015

Note: CAP values are aggregated values of Maricopa, Pima, and Pinal Counties. Surface water sources include all sources; they are not exclusive to the Colorado River.

[1] The 2015 USGS water-use (for specific purposes, such as irrigation) data by source (surface water or groundwater, etc.) is the most recent available county-level data.

[2] Coconino County is included in the Arizona study area due to the potential for recreation-related impacts, but it does not receive Colorado River irrigation water and is excluded from this table.

Industrial and Municipal Water Uses

Data indicate that demands for municipal water are increasing across the SEIS socioeconomic study area, while projected water availability is decreasing (see, for example, Warziniack and Brown 2019). While this trend is seen throughout the western US, the Colorado River region has the largest percentage increases in projected domestic and public water use as well as the greatest percentage decreases in projected water yield (Warziniack and Brown 2019).

As described in the 2007 FEIS, municipalities potentially affected by the proposed alternatives include the cities of Phoenix, Tucson, Scottsdale, and other Arizona towns and cities served by the CAP, as well as Arizona municipalities along the Colorado River, such as Lake Havasu City, that have post-1968 Colorado River water delivery contracts. Industrial land uses in Arizona on the Colorado River include the major power facilities of Glen Canyon Dam in Coconino County, Hoover and Davis Dams on the Arizona-Nevada border in Mohave County (and Clark County, Nevada) and Parker Dam in La Paz County (and San Bernardino County, California).

California

Population

In California, the population has increased by approximately 7.7 percent in the past decade. With the exception of Los Angeles, the study area counties' growth all surpassed that of the state. The largest increase in population was in Riverside County (14.2 percent; see **Table 3-94**).

Table 3-94
California Population 2010–2021

	Imperial County	Los Angeles County	Orange County	Riverside County	San Bernardino County	San Diego County	California
Population 2010	168,052	9,758,256	2,965,525	2,109,464	2,005,287	3,022,468	36,637,290
Population 2021	180,051	10,019,635	3,182,923	2,409,331	2,171,071	3,296,317	39,455,353
Percent change 2010–2021	7.1	2.7	7.3	14.2	8.3	9.1	7.7

Source: Headwaters Economics Economic Profile System 2023

Employment

Full- and part-time employment in California totaled 23.9 million jobs in 2004, an increase of approximately 3.9 million jobs from 2004 levels. Full- and part-time employment in the six-county study area totaled 13 million jobs in 2021, representing 55 percent of total California employment. Farm employment was higher than the California state average (1.0 percent) in Imperial County (5.2 percent) and lower in all other counties (see **Table 3-95**).

Table 3-95
California Employment by Industry (2021)

	Imperial County	Los Angeles County	Orange County	Riverside County	San Bernardino County	San Diego County	California
Total employment	82,115	6,428,159	2,253,070	1,127,161	1,122,017	2,131,117	23,906,353
Wage and salary employment	67,229	4,597,519	1,675,102	813,146	858,597	1,619,417	17,891,462
Proprietors' employment	14,886	1,830,640	577,968	314,015	263,420	511,700	6,014,891
Farm employment (number and percentage of total employment)	4,229	4,110	1,363	7,293	2,467	10,820	229,419
	5.2%	0.1%	0.1%	0.6%	0.2%	0.5%	1.0%
Non-farm employment (number and percentage of total employment)	77,886	6,424,049	2,251,707	1,119,868	1,119,550	2,120,297	23,676,934
	94.8%	99.9%	99.9%	99.4%	99.8%	99.5%	99.0%
Forestry, fishing, and related	6,934	2,747	1,327	6,950	1,153	3,030	250,669
	8.4%	<0.0%	0.1%	0.6%	0.1%	0.1%	1.0%
Mining, quarrying, and oil and gas extraction	395	5,738	2,436	1,689	1,351	1,810	33,528
	0.5%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%
Utilities	525	13,326	3,403	1,903	3,898	5,465	65,390
	0.6%	0.2%	0.2%	0.2%	0.3%	0.3%	0.3%
Construction	2,501	252,952	132,853	98,788	60,656	113,440	1,253,884
	3.0%	3.9%	5.9%	8.8%	5.4%	5.3%	20.8%
Manufacturing	2,532	341,233	158,005	49,600	56,632	123,412	1,375,410
	3.1%	5.3%	7.0%	4.4%	5.0%	5.8%	5.8%

	Imperial County	Los Angeles County	Orange County	Riverside County	San Bernardino County	San Diego County	California
Wholesale trade	2,222	242,952	90,733	32,519	48,346	51,850	731,178
	2.7%	3.8%	4.0%	2.9%	4.3%	2.4%	3.1%
Retail trade	9,604	520,666	185,913	120,232	112,569	176,273	2,031,941
	11.7%	8.1%	8.3%	10.7%	10.0%	8.3%	8.5%
Transportation and warehousing	3,686	398,305	73,131	104,835	163,147	83,983	1,371,207
	4.5%	6.2%	3.2%	9.3%	14.5%	3.9%	5.7%
Information	D	252,429	30,588	8,228	6,621	28,470	643,367
	D	3.9%	1.4%	0.7%	0.6%	1.3%	2.7%
Finance and insurance	1,896	320,290	166,014	42,930	37,784	106,550	1,191,722
	2.3%	5.0%	7.4%	3.8%	3.4%	5.0%	5.0%
Real estate rental and leasing	1,962	393,202	157,319	53,359	42,016	115,531	1,250,434
	2.4%	6.1%	7.0%	4.7%	3.7%	5.4%	5.2%
Professional, scientific, and technical services	2,021	520,666	220,542	52,231	46,030	232,087	2093532
	2.5%	8.1%	9.8%	4.6%	4.1%	10.9%	8.8%
Management of companies and enterprises	178	77,980	42,667	4,674	5,587	27,703	277,998
	0.2%	1.2%	1.9%	0.4%	0.5%	1.3%	1.1%
Administrative, support, and waste management	3,459	406,452	198,480	85,653	89,927	132,174	1,526,406
	4.2%	6.3%	8.8%	7.6%	8.0%	6.2%	6.4%
Educational services	387	172,964	53,545	14,692	16,275	46,095	543,623
	0.5%	2.7%	2.4%	1.3%	1.5%	2.2%	2.3%
Health care and social assistance	11,023	855,509	159,818	129,950	134,728	218,439	2,822,918
	13.4%	13.3%	7.1%	11.5%	12.0%	10.2%	11.8%
Arts, entertainment, and recreation	348	223,083	56,418	22,842	14,023	47,031	566,938
	0.4%	3.5%	2.5%	2.0%	1.2%	2.2%	2.4%
Accommodation and food services	4,452	408,321	159,818	86,805	14,023	152,988	1,575,223
	5.4%	6.4%	7.1%	7.7%	1.2%	7.2%	6.6%
Other services	D	414,016	123,440	72,847	73,055	115,935	1,346,871
	D	6.4%	5.5%	6.5%	6.5%	5.4%	5.6%
Government and government enterprises	19,271	600,175	160,559	129,141	65,928	338,030	2,724,695
	23.5%	9.3%	7.1%	11.5%	5.9%	15.9%	11.4%

Source: Bureau of Economic Analysis 2023a
(D) = Not shown to avoid disclosure of confidential information; estimates are included in higher-level totals.

Personal Income

Total personal income in California totaled $3 trillion in 2024, compared with $1.84 trillion in 2004 (when adjusted for inflation). Statewide per capita income also increased from approximately $49,435 in 2004 (adjusted for inflation) to approximately $76,614 in 2021 (Bureau of Economic Analysis 2023b; see **Table 3-96**).

In 2004, total personal income ranged from a low of approximately $8.5 billion in Imperial County to a high of $728.8 billion in Los Angeles County. When combined, the total personal income of the six counties represents 48.8 percent of the state total. Per capita income ranged from a low of approximately $47,653 in Imperial County to a high of approximately $81,034 in Orange County.

Table 3-96
California Personal Income and Earnings (2021)

	Imperial County	Los Angeles County	Orange County	Riverside County	San Bernardino County	San Diego County	California
Personal income ($1,000s)	$8,570,390	$728,772,915	$256,700,438	$125,820,553	$108,623,799	$238,691,713	$3,006,183,929
Per capita personal income	$47,653	$74,141	$81,034	$51,180	$49,493	$72,637	$76,614
Earnings by place of work	$5,137,777	$510,862,232	$181,016,988	$64,353,758	$69,548,586	$167,563,948	$2,102,644,661
Wages and salaries	$3,249,301	$359,122,730	$128,811,520	$45,029,294	$49,466,149	$123,893,955	$1,533,988,242
Supplements to wages and salaries	$1,122,878	$78,557,777	$26,652,410	$11,516,385	$12,705,654	$29,637,025	$314,285,006
Proprietors' income	$765,598	$73,181,725	$25,553,058	$7,808,079	$7,376,783	$14,032,968	$254,371,413

Source: Bureau of Economic Analysis 2023b.

Agriculture

The percentage of cropland that is irrigated in the California study area, with an average of 94 percent—which is the same as the percentage of irrigated cropland for all of California—varies across the different counties. The percentage of irrigated cropland ranges from a low of 68 percent in Orange County to a high of 98 percent in Imperial County. The proportion of irrigated croplands within the California study area represents approximately 12 percent of total irrigated croplands in the state. **Table 3-97** shows acres of irrigated and total cropland within the California study area.

Table 3-97
Irrigated Acres of Harvested Agriculture in the California Study Area (2017)[1]

Area	Irrigated Cropland (Acres)	Total Cropland (Acres)	Percent Irrigated Cropland
Imperial County	455,768	467,445	98
Los Angeles County	10,104	12,806	79
Orange County	3,946	5,803	68
Riverside County	125,363	143,628	87
San Bernardino County	21,487	22,145	97
San Diego County	41,607	49,080	85
Total California Study Area	**876,272**	**915,647**	**94**
California	**7,348,690**	**7,857,512**	**94**

Source: USDA 2019b

[1] The 2017 agricultural census from the National Agricultural Statistics Service (used in reports developed by Duval et al. 2020) provides the most recent available data on the market value of agricultural production at the county level. The next agricultural census data release is due in the spring/summer 2024.

Industrial and Municipal Water Uses

As noted in the 2007 FEIS, municipalities potentially affected by the proposed alternatives include 88 cities in Los Angeles County, 34 cities in Orange County, 24 cities in Riverside County, 31 cities in San Bernardino County, and 18 cities in San Diego County.

Nevada

Population

Following trends seen in other study area states, the population of Nevada grew by over 16 percent in the last 10 years. Clark County's population change (17.7 percent) was higher than that of the state overall (see **Table 3-98**).

Table 3-98
Nevada Population 2010–2021

	Clark County	Nevada
Population 2010	1,895,521	2,633,331
Population 2021	2,231,147	3,059,238
Percent Change 2010–2021	17.7	16.2

Source: Headwaters Economics Economic Profile System 2023

Employment

Full- and part-time employment in Nevada totaled 1,875,709 jobs in 2021, an increase of approximately 472,402 jobs from 2004 levels. In 2021, employment in the arts, entertainment, and recreation sector totaled 55,322 jobs or approximately 3 percent of total employment in the state. Farm employment represented only 0.3 percent of total employment.

Full- and part-time employment in Clark County totaled 1,368,492 jobs in 2021, an increase of approximately 370,492 jobs from 2004. Total employment in Clark County represents almost 70 percent of total employment in Nevada. Full- and part-time employment in the Clark County government sector was lower than the Nevada average (United States Department of Commerce, Bureau of Economic Analysis 2006e). In 2021, employment in the arts, entertainment, and recreation sector totaled 41,400 jobs or approximately 3 percent of total employment in the county. Similar to statewide totals, farm employment represented only 0.03 percent of total employment. See **Table 3-99**.

Table 3-99
Nevada Employment by Industry (2021)

	Clark County	Nevada
Total employment	1,368,492	1,875,709
Wage and salary employment	1,019,149	1,409,465
Proprietors' employment	349,343	466,244
Farm employment (number and percentage of total employment)	409	5,028
	<0.0%	0.3%
Non-farm employment (number and percentage of total employment)	1,368,083	1,870,681
	>99.9%	99.7%

	Clark County	Nevada
Forestry, fishing, and related	457	1,937
	<0.0%	0.1%
Mining, quarrying, and oil and gas extraction	1,577	4,526
	0.1%	0.2%
Utilities	86,255	4,526
	6.3%	0.2%
Construction	86,255	120,249
	6.3%	6.4%
Manufacturing	29,758	66,978
	2.2%	3.6%
Wholesale trade	29,275	43,982
	2.1%	2.3%
Retail trade	136,244	185,306
	10.0%	9.9%
Transportation and warehousing	104,271	137,427
	7.6%	7.3%
Information	15,961	21,137
	1.2%	1.1%
Finance and insurance	80,765	103,909
	5.9%	5.5%
Real estate rental and leasing	79,184	110,419
	5.8%	5.9%
Professional, scientific, and technical services	79,184	109,638
	5.8%	5.8%
Management of companies and enterprises	79,597	32,573
	5.8%	1.7%
Administrative, support, and waste management	26,541	132,423
	1.9%	7.1%
Educational services	16,473	21,845
	1.2%	1.2%
Health care and social assistance	118,625	160,792
	8.7%	8.6%
Arts, entertainment, and recreation	41,400	55,322
	3.0%	2.9%
Accommodation and food services	229,369	276,961
	16.8%	14.8%
Other services	67,012	89,948
	4.9%	4.8%
Government and government enterprises	119,106	177,141
	8.7%	9.4%

Source: Bureau of Economic Analysis 2023a
(D) = Not shown to avoid disclosure of confidential information; estimates are included in higher-level totals.

Personal Income

Total personal income in Nevada totaled $189.3 billion in 2021, an 89 percent increase over 2004 levels (when adjusted for inflation). Statewide per capita income increased from approximately $23,800 in 1994 (inflation-adjusted levels) to approximately $33,800 in 2004. See **Table 3-100.**

In 2021, per capita income in Clark County was $58,276, which was slightly lower than the state average. The total personal income of Clark County represents more than 70 percent of the state total. See **Table 3-100**.

Table 3-100
Nevada Personal Income and Earnings (2021)

	Clark County	Nevada
Personal income ($1,000s)	$133,596,955	$189,308,244
Per capita personal income	$58,276	$ 60,213
Earnings by place of work	$83,182,161	$117,154,278
Wages and salaries	$60,447,133	$ 84,993,156
Supplements to wages and salaries	$13,352,162	$ 19,168,471
Proprietors' income	$9,382,866	$ 12,992,651

Source: Bureau of Economic Analysis 2023b
(D) = Not shown to avoid disclosure of confidential information; estimates are included in higher-level totals.

Agriculture

Agriculture in the Nevada study area was relatively small (2,722 acres; less than 0.01 percent of the agricultural study area) compared with the agricultural areas in Arizona and California study areas. The Nevada agricultural study area was also relatively small (0.5 percent) compared with total agricultural cropland in the state. Of the total harvested agricultural lands in Clark County, which makes up the Nevada study area, 100 percent were irrigated cropland, which is comparable with the percentage of irrigated cropland in Nevada (99 percent). **Table 3-101** shows acres of irrigated and total cropland within the Nevada study area.

Table 3-101
Irrigated Acres of Harvested Agriculture in the Nevada Study Area (2017)[1]

Area	Irrigated Cropland (Acres)	Total Cropland (Acres)	Percent Irrigated Cropland
Clark County	2,722	2,722	100
Total Nevada	**567,978**	**573,785**	**99**

Source: USDA 2019c
[1] The 2017 agricultural census from the National Agricultural Statistics Service (used in reports developed by Duval et al. 2020) provides the most recent available data on the market value of agricultural production at the county level. The next agricultural census data release is due in the spring/summer 2024.

Municipal and Industrial Water Use

As noted in the 2007 FEIS, municipalities potentially affected by the proposed alternatives include Boulder City, Henderson, Las Vegas, and North Las Vegas due to their reliance on Colorado River water supplied by SNWA.

Utah

The counties in the Utah study area are not anticipated to be impacted by agricultural, industrial, or municipal water shortages as a result of proposed management. As a result, no detailed information is included for the population, employment, and income, or the agriculture, municipal, or industrial uses in the study area.

Economic Contributions from Recreation

As discussed in **Section 3.14**, Recreation, recreational activities with the potential to be impacted by proposed management include recreation (boating, camping, hiking, etc.) on and adjacent to reservoirs at Lake Powell and Lake Mead, as well as river-based recreation downstream in Glen Canyon and Grand Canyon.

Economic benefits result when visitors spend dollars on recreation. Those benefits include increased sales, income, and jobs. Direct economic benefits occur when businesses sell goods and services to area visitors. Additional jobs and economic activity are supported when businesses purchase supplies and services from other local businesses, thus creating indirect effects from visitor spending. In addition, employees use their income to purchase goods and services in the local economy, generating further induced effects from visitor spending.

Table 3-102, below, displays the total economic contributions from recreation occurring in the GCNRA, LMNRA, and GCNP. Economic contributions result when visitors spend dollars on recreation. Those contributions include increased sales, income, and jobs. Direct economic contributions occur when businesses sell goods and services to area visitors. Additional jobs and economic activity are supported when businesses purchase supplies and services from other local businesses, thus creating indirect effects from visitor spending. In addition, employees use their income to purchase goods and services in the local economy, generating further induced effects from visitor spending.

Economic contributions are estimated by multiplying total visitor spending by regional economic multipliers. Total visitor spending includes spending by both local visitors who live in gateway regions and nonlocal visitors who travel to NPS sites from outside gateway regions. Spending by nonlocal visitors represents an influx of dollars from outside the local economy. In addition, nonlocal visitors typically have higher levels of spending on food, lodging, and other activities on a per-trip basis.

The GCNRA, LMNRA, and GCNP had 96 percent, 88 percent, and 99 percent of spending from nonlocal visitors, respectively. A discussion of recreation-related economic activity occurring on the Colorado River downstream of Lake Powell and Lake Mead was not included; this is because no change in recreation and resulting changes in economic activity are expected under the proposed alternatives. For additional details on recreation and levels of use, see **Section 3.14**, Recreation.

Table 3-102
Summary of Economic Contributions for NPS Based Recreation (2021)

NPS Unit	Total Recreation Visits	Visitor Spending (1,000s of 2021$)	Jobs	Labor Income (1,000s of 2021$)	Value Added (1,000s of 2021$)	Economic Output (1,000s of 2021$)	% of Spending from Nonlocals
GCNRA	3,144,318	$332,150	3,839	$139,418	$234,458	$409,546	96
GCNP	4,352,667	$710,256	9,390	$324,318	$539,433	$944,693	99
LMNRA	7,603,474	$373,668	4,054	$167,550	$281,033	$457,279	88

Source: NPS 2022c

Note: Jobs measure annualized full- and part-time jobs that are supported by NPS visitor spending. Labor income includes employee wages, salaries, and payroll benefits, as well as the incomes of proprietors that are supported by NPS visitor spending. Value added measures the contribution of NPS visitor spending to the GDP of a regional economy. Value added is equal to the difference between the amount an industry sells a product for and the production cost of the product. Economic output is a measure of the total estimated value of the production of goods and services supported by NPS visitor spending. Economic output is the sum of all intermediate sales (business to business) and final demand (sales to consumers and exports).

As shown in **Table 3-131**, below, recreational visits to GCNRA and GCNP correspond with a wide array of job sectors within local (predominately small town and rural) economies. In 2021, GCNRA recreation supported 3,839 jobs (including 921 indirect and induced jobs), and GCNP recreation supported 9,390 jobs (including 2,243 indirect and induced jobs) (NPS 2022c). Specific job data are unavailable for LMNRA. However, LMNRA recreation supported 4,054 total jobs in 2021.

Table 3-103
Jobs by Sector Supported by Economic Contributions from NPS-Based Recreation (2021)

	GCNRA	GCNP
Direct Jobs by Sector		
Camping	76	143
Gas	73	94
Groceries	98	127
Hotels	1,200	2,400
Recreation industries	610	1,880
Restaurants	580	1,500
Retail	155	439
Transportation	126	564
Indirect and Induced Jobs	**921**	**2,243**
Total Jobs	**3,839**	**9,390**

Source: NPS 2022c

In addition to general recreation sector contributions, visitor use supports concessionaires, including those associated with water-based recreation. Contributions from GCNRA concessioners and small business permittees are estimated at $130 million annually in gross receipts (NPS 2022d). This spending represent an important contribution to local communities in Coconino County in Arizona and Garfield, San Juan, Wayne, and Kane County in Utah. Based on communication with the NPS, the State of Utah believes recreational access to Lake Powell contributes up to $8 million to the state's economy.

In terms of river-based recreation, it is estimated that Grand Canyon River outfitters retain roughly 1,100 employees, not including the contracted transportation and training services and numerous food, sundries, and river supply vendors required to support the operations.[22]

In addition to the direct economic impact on GCNP and the NPS, it is estimated that the regional economic impact of commercial river trips sustains hundreds of additional jobs and generates millions more of additional revenue throughout the mostly rural communities and small businesses of northern Arizona and southern Utah each season.

All river recreation in GCNP is regulated through the NPS CRMP (to protect the resource and the visitor experience). These river trips are closely regulated, and this experience is generally reserved an average of 12–18 months in advance. River trips include approximately 22,000 visitors annually, generating more than $50 million in revenues to the region (NPS 2006).

3.16.2 Environmental Consequences

Methodology

Agriculture

The purpose of the agricultural impact assessment is to estimate the change in agricultural production as a result of a reduction of irrigation water. The change in the value of agricultural production is directly related to acres of cropland chosen to be fallowed and the estimated revenue per acre of the fallowed crop. In addition to revenue loss from agricultural products, agricultural jobs and wages would potentially be lost.

The current analysis applied the 2007 agricultural modeling framework, using crops' profitability in each county to determine which crops farmers are most likely to fallow. In this analysis, water shortages are assumed to result in temporary acres of fallowed cropland during the period in which shortages would occur. While farmers may use groundwater and other surface water resources to mitigate impacts from allocated shortages, it is difficult to project exactly how individual farmers, irrigation districts, or each of the Lower Division States may mitigate potential, future agricultural impacts from shortages. Therefore, similar to the assumption made in the 2007 FEIS, the projected change in agricultural production was based on the conservative assumption that other sources of water would not replace the estimated water shortage.

The decision to fallow lands is based on the farmer's ability to cover the variable cost of production of a given crop. If the cost of water exceeds the maximum amount a farmer can pay or if water is not available, a crop is taken out of production and the land is fallowed during the year shortages would occur. Considering crop profitability gives an indication of crops that face larger reductions compared with other crops (Dale and Dixon 1998; Frisvold et al. 2012). The least profitable crop

[22] Personal communication provided from Laurie Dyer, the NPS Supervisory Concessions Management Specialist in the Commercial Services Division at GCNP, on March 15, 2023.

would be fallowed first. Crops would continue to be fallowed in the order of least profitable crop, until the full volume of water shortage is offset or until the crop is completely fallowed within the county.

Irrigated crops in the planning area include field crops, vegetables and melons, and trees and vines. Field crops have lower earnings per acre-foot of water than other crops; therefore, they are more vulnerable to changes in water costs and shortages. Studies on fallowing patterns in the southwestern US show that field crops account for 98 to 100 percent of fallowed crops (Frisvold et al. 2012; Dale and Dixon 1998). Fallowed crops for the No Action Alternative were limited to cotton, wheat, and alfalfa. To account for the higher shortage volumes under the action alternatives, additional crops, including vegetables and other field crops such as forage and grain crops produced for silage and green chop, were included in the analysis. Crops considered in this analysis included irrigated crops for which data were available; farmers may choose to fallow other crops, such as corn or other forage and grain crops, for which data were unavailable or unreliable.

Calculation of crop profitability per acre-foot of water followed the method outlined in Appendix H of the 2007 FEIS, which used the difference between revenue and variable costs per acre of land required to grow a given crop. In the Arizona and Nevada planning areas, calculations were updated with the most recent available data from the US Department of Agriculture[23] (USDA 2019a); county-level revenue for each crop was based on 5-year (2014 to 2018) averages of yield[24] and prices. The US Department of Agriculture does not provide recent county-level data for California; yield, acreage, and price data for the California analysis area between 2014 and 2018 were obtained from reports produced by each county's agricultural commissioner/weight and measures departments (Imperial County 2014, 2015, 2016, 2017, 2018; Riverside County 2014, 2015, 2016, 2017, 2018; San Bernardino County 2014, 2015, 2016, 2017, 2018).

County-level production cost data for each crop, including the difference in irrigation cost, are not updated frequently. To capture the difference in the irrigation cost for each crop in different counties in Arizona, variable costs-of-production estimates were based on historical crop and livestock budgets developed by the University of Arizona (University of Arizona 2001) for 1999; these were the same cost-of-production data used in the 2007 analysis. For the California counties, estimates were based on budgets developed by the University of California Davis (UC Davis 2023) for a range of years (from 1970 to 2004, depending on the type of crop and the county for which it was developed). All dollar values were converted to 2022 dollars. The purpose of using the cost estimates was only to determine the order in which crops would be fallowed; the estimates are not considered an accurate measure of the current cost and return estimates.

To determine how much a farmer would be willing to pay for water before a choice is made to fallow a crop, the irrigation cost of growing each crop was added back to the calculated revenue over the variable production cost. To account for each crop's required amount of water (different for

[23] The most recent available yield and price data for alfalfa hay were from 2018. More recent cotton and wheat data (2019 to 2022) were available; however, for consistency across the different crops, 2018 data were the latest data used in this analysis.

[24] The cottonseed revenue estimates that were included in the 2007 model were excluded from current revenue estimates due to a lack of county-level yield data for cottonseed in Arizona.

each crop), the estimated return plus irrigation cost was divided by the amount of water per acre[25] needed to grow that crop (University of Arizona 2001; UC Davis 2023). Based on this method, the order in which crops would be fallowed varied across the counties in the planning area. In Arizona and Nevada, cotton is most likely to be fallowed first. In California, wheat and alfalfa would be fallowed before cotton; vegetables are expected to be fallowed last in the entire planning area.

As in the 2007 FEIS, the socioeconomic effects of changes in agricultural production in Arizona were analyzed using the IMPLAN input-output economic model. IMPLAN is a regional economic model that describes the flows from producers to intermediate and final consumers using a series of economic multipliers. The IMPLAN model describes for each county the transfers of money between all industries and institutions. This model of county-level economic interactions is used to project total changes to regional economic activity based on the direct change estimated in agricultural production. In addition to the direct loss in agricultural output, reduced expenditures occur from a drop in business-to-business purchases and in reduced household expenditures. These changes, known as indirect and induced economic effects, were also estimated using IMPLAN.

Impact Analysis Area

Potential changes in agricultural production within the analysis area due to estimated shortages were quantitatively assessed for the counties expected to experience impacts; these include La Paz, Maricopa, Mohave, Pima, Pinal, and Yuma Counties in Arizona; Imperial, Riverside, and San Bernardino Counties in California; and Clark County in Nevada.

Assumptions

- Farmers would fallow irrigated crops in response to water shortages or an increased cost of irrigation.
- Farmers would fallow crops that generate the lowest returns per acre-foot of water.
- Crops have a constant profitability per acres of land and per acre-foot of water.
- Changes in the amount of irrigated water would be the result of changes in water allocations from the Colorado River sources (such as from CAP); they do not involve changes to irrigation water from groundwater.
- Estimated shortages in the agricultural sector are based on the Shortage Allocation Model (**Appendix D**). This model accounts for shortages currently allocated to non-consumptive use (such as for conservation programs) under both action alternatives. Therefore, total water shortage estimates represent higher levels of shortage than would be seen in actual consumptive uses of water (that is, agriculture, municipal, and industrial).
- For Action Alternative 1 and the No Action Alternative, available water is distributed in proportion to entitlements unless specifically provided otherwise. A shortage results when water available to an entity is less than its expected use.[26]
- For Action Alternative 2, 2021 adjusted consumptive use is the baseline by which shortages are calculated (with the exception of parties within CAP; see below).

[25] Water (per acre) required by a particular crop is assumed to be relatively constant over time.
[26] Different states and/or priorities have different assumptions; see **Appendix D**.

- For all alternatives, available water is distributed within the CAP based on the CAP priority system, and shortage volumes are calculated relative to scheduled 2024–2026 use. Non-Indian CAP agricultural districts do not hold long-term contacts for project water, but they are shown as absorbing significant shortage based on their access to and historical use of the CAP excess water pool.
- In most cases, the contractor or recipient of an allocation is shown as the entity bearing shortage, by sector. In some cases, water allocated for one sector of use (for example, Indian agriculture) may be leased for other uses (that is, municipal use). No attempt is made in this analysis to track actual end use of the water allocation due to uncertainties of this end use.

Impact Indicators

- Acres of fallowed cropland
- Crop profitability per acre-foot of water
- Jobs and income associated with agriculture

Recreation

A qualitative discussion is provided related to social and economic impacts from changes in recreational access and experiences as a result of changes in reservoir elevations and river flows, as discussed in **Section 3.14**, Recreation.

In addition, a discussion of net economic value changes is provided for a subset of recreational activities, including for anglers and whitewater rafters in Glen and Grand Canyons. This analysis is provided following the approach used in the recreation economic analysis for the LTEMP EIS (Gaston et al. 2015). Models were informed from past survey research and used to project the change in net economic value for angling in Glen Canyon and whitewater rafting in Grand Canyon; these were compared with Action Alternative 1 and the No Action Alternative scenarios. The analysis was based on whitewater boater and angler surveys that examined different river flow scenarios to estimate the net economic value of an individual trip, as a function of river flow. The function used to estimate the net economic value is for conditions where within-day fluctuations are less than 10,000 cfs, consistent with the action alternatives and No Action Alternative.

Impact Analysis Area

Counties adjacent to the Colorado River from Lake Powell to the SIB

Assumptions

- Recreation spending per trip for anglers and whitewater rafting (adjusted for inflation) would follow results from willingness-to-pay surveys (Gaston et al. 2015) with variation based on river flows.

Impact Indicators

Recreation economic contributions

Municipal and Industrial Uses

Impacts on municipal and industrial uses of water are discussed qualitatively based on anticipated water shortages of various magnitudes, as determined under the Shortage Allocation Model. The analysis then examines whether a particular shortage event would affect the M&I sector as compared with the No Action Alternative. For example, a shortage in Arizona would affect parts of the agricultural sector first before affecting M&I uses. In contrast, a shortage in Nevada would primarily affect M&I users, because Nevada has a small agricultural sector that uses high-priority Colorado River water.

For situations likely to have an effect on the M&I sector, the ability of each state to manage shortages to the M&I sector were analyzed. The M&I shortages allocated to each state were compared with the drought plans or actions that state or local agencies could institute during a shortage. The analysis then qualitatively discussed whether such drought planning mechanisms are adequate to address shortages to the M&I sector.

Impact Analysis Area

The analysis area for M&I water shortages is the same as the overall analysis area for socioeconomics, as described in **Section 3.15.1**.

Assumptions

The analysis is based on shortage levels as modeled in the Shortage Allocation Model.

Impact Indicators

The potential for economic impacts as a result of anticipated shortages

Issue 1: How would anticipated water shortages affect economic contributions from agriculture?

Summary

Anticipated water shortages would result in a temporary increase in acres of fallowed cropland and agricultural production loss under all alternatives. Under the action alternatives, the shortage scenarios would result in a greater level of short-term impacts on agricultural production, associated jobs, income, and tax revenue, compared with the No Action Alternative. However, in the long term, preservation of reservoir levels above a critical value (dead pool) due to the proposed shortage scenarios are anticipated to lessen the need for more severe restrictions and long-term (potentially permanent) economic impacts.

The No Action Alternative has the potential to result in $100 million to $116 million in agricultural revenue loss, $60 million to $100 million in income loss from jobs lost, and $9 to $21 million in tax revenue loss. Impacts would be limited to Arizona under the No Action Alternative.

Action Alternative 1 would result in $82 million to $207 million in agricultural revenue loss, $87 million to $115 million in income loss, and $14 to $31 million in tax revenue loss in 2024; during this period, impacts would be limited to Arizona. The maximum shortage scenario (4.000 maf) in 2025 and 2026 would result in a $743 million loss of revenue, $452 million loss of income, and $192 million loss of tax revenue in Arizona. In 2025 and 2026, in addition to Arizona, Riverside and Imperial Counties in California would also experience economic impacts including $185 million in lost income and $66 million in lost tax revenue.

Under Action Alternative 2, agricultural revenue would decrease $125 million to $457 million in 2024. Under the maximum shortage scenario (4.000 maf) in 2025 and 2026, the agricultural revenue loss would increase to $918 million. Under this alternative, the planning areas in Arizona, California, and Nevada would experience impacts during 2024 through 2026. Total impacts on income from jobs lost in Arizona would range between $81 million and $164 million in Arizona and $9 and $64 million in California; the tax revenue loss would range between $14 million and $25 million in Arizona and $3 and $23 million in California in 2024. Under the maximum shortage scenario in 2025 and 2026, the income loss would increase to $290 million in Arizona and $165 in California, and tax revenue loss would increase to $60 million in Arizona and $50 million in California. In this analysis, impacts on jobs, income, and tax revenue from agricultural impacts were not evaluated for Nevada.

No Action Alternative

Temporary impacts (during periods of lower water elevations) from allocated shortages under the No Action Alternative (200,000 af to 1.100 maf of water) would result in 50,000 to 94,000 acres of fallowed cropland, and $100 to $116 million in loss of agricultural production. The impacts would be restricted to the Arizona planning area and would be limited to field crops. Under the No Action Alternative, cotton, wheat, and hay were analyzed in detail, and impacts did not extend to additional crops. **Table 3-104** shows the total estimated acres of fallowed cropland and the reduction in dollar value of agricultural production, for different shortage volumes under the No Action Alternative.

Table 3-104
Acres of Fallowed Cropland and the Loss of Market Value of Agricultural Production in Arizona – No Action Alternative

Shortage Amount (1,000 af)	Non-Indian Agriculture		Indian Agriculture		Total Agriculture in the Study Area	
	Fallowed Cropland (Acres)	Change in Production Value	Fallowed Cropland (Acres)	Change in Production Value	Fallowed Cropland (Acres)	Change in Production Value
200	49,797	$100,292,274	0	$0	49,797	$100,292,274
533	73,023	$101,169,138	0	$0	73,023	$101,169,138
617	82,079	$100,292,274	2,456	$3,052,073	84,535	$103,344,347
867	82,734	$101,169,138	5,387	$6,693,991	88,121	$107,863,129
917	82,734	$101,169,138	5,387	$6,693,991	88,121	$107,863,129
967	82,734	$101,169,138	5,387	$6,693,991	88,121	$107,863,129
1,017	82,734	$101,169,138	5,387	$6,693,991	88,121	$107,863,129
1,100	83,480	$102,932,699	10,821	$12,967,706	93,783	$115,900,405

Source: Values were calculated using input from the Shortage Allocation Model and crop profitability, according to the methodology described above. Note: Modeling results should only be used to compare the relative magnitude of impacts that are reasonably expected to occur under the alternatives. The results are not a substitute for agricultural production loss estimates in the analysis area; the results are subject to uncertainties from built-in assumptions and data limitations.

For those Tribes identified by Reclamation to use the full or a substantial amount of their entitled water for agricultural operations, this analysis assumed 100 percent of consumptive-use water, as well as allocated shortages, were used for irrigation; the exact proportion of water used for agricultural operations for these Tribes was not known.

Due to data limitations for Indian agriculture, such as those involving privacy concerns, particularly for Tribes where three or fewer farms for a given crop exist, estimates did not account for the full allocated shortage volumes. Therefore, economic impacts may be larger than the estimated values.

While non-Indian agriculture is expected to experience short-term impacts for every allocated shortage amount, lower shortage volumes (between 200,000 and 533,000 af) would not result in impacts on Indian agriculture. However, for shortages greater than 617,000 acre-feet, $3 to $13 million in agricultural production loss would be due to fallowed Indian agricultural lands, which account for 3 to 11 percent of total agricultural production loss in the study area.

In the long term, if the current guidelines of the No Action Alternative remained in effect, the water levels would be expected to decline below a critical level in Lake Mead; if water levels decline below this threshold, farmers across the planning areas in Arizona, California, and Nevada would experience long-term (potentially permanent) production loss from fallowed crops.

Table 3-105 provides an overview of the jobs, income, and total economic output associated with the estimated change in agricultural production value due to fallowed crops under each shortage level for the No Action Alternative. This analysis covers anticipated shortages for operating years 2024 through 2026. **Table 3-106** provides an overview of the change to tax revenue from agricultural production losses over the same period. Shortages under the No Action Alternative, and related economic impacts, are limited to Arizona agriculture.

Table 3-105
Estimated Jobs and Income under the No Action Alternative

Shortage Amount (1,000 af)	Non-Indian Agriculture		Indian Agriculture		Total	
	Total Jobs	Total Income	Total Jobs	Total Income	Total Jobs	Total Income
200	657	$60,442,632	0	0	657	$60,442,632
533	1,082	$86,379,768	0	0	1,082	$86,379,768
617	1,506	$97,314,296	31	$2,780,000	1,537	$89,379,768
867	1,539	$98,108,605	68	$6,097,798	1,607	$100,094,296
917	1,539	$98,108,605	68	$6,097,798	1,607	$104,206,403
967	1,539	$98,108,605	68	$6,097,798	1,607	$104,206,403
1,017	1,539	$98,108,605	68	$6,097,798	1,607	$104,206,403
1,100	1,526	$99,877,874	88	$8,368,185	1,613	$108,274,059

Source: Agricultural model output and IMPLAN 2021 software and data
Note: Total jobs include direct, indirect, and induced jobs. Due to model limitations and market uncertainties, modeling results should only be used to compare the relative magnitude of impacts that are reasonably expected to occur under the alternative.

Table 3-106
Estimated Tax Revenue Change under the No Action Alternative

Shortage Amount (1,000 af)	Non-Indian Agriculture	Indian Agriculture
200	$10,625,983	0
533	$14,457,659	0
617	$16,330,902	$2,087,855
867	$16,468,180	$4,579,323
917	$16,468,180	$4,579,323
967	$16,468,180	$4,579,323
1,017	$16,468,180	$4,579,323
1,100	$16,970,661	$6,404,036

Source: Agricultural model output and IMPLAN 2021 software and data
Note: Total includes local, state, and federal tax revenue. Tax amounts are impacted by agricultural subsidies. The agriculture Sectors in IMPLAN see significant amounts of government subsidies. Because tax revenue is net of subsidies, it can be negative for a given industry in a given year, if that industry received more subsidies from the government than it paid out in these specific taxes in that year. Due to model limitations and market uncertainties, modeling results should only be used to compare the relative magnitude of impacts that are reasonably expected to occur under the alternative.

Action Alternative 1

During 2024, under Action Alternative 1, 72,423 to 158,050 acres of cropland in Arizona would temporarily be fallowed; this would result in a loss of $82 to $207 million in agricultural production. Similar to the No Action Alternative, this would be limited to loss primarily from fallowed field crops. Indian agriculture would experience impacts at allocated shortages above 1.066 maf and would account for approximately 27 to 33 percent of total impacts in agricultural production**. Table 3-107** shows the total estimated acres of fallowed cropland and the reduction in market value of agricultural production in Arizona for different shortage amount in 2024, under Action Alternative 1. There would be no impacts in the California and Nevada study areas in 2024.

Due to data limitations for Indian agriculture, such as those involving privacy concerns, particularly for Tribes where three or fewer farms for a given crop exist, estimates did not account for the full allocated shortage volumes. Therefore, economic impacts may be larger than the estimated values. Under Action Alternative 1, temporary agricultural impacts due to shortage allocations up to 2.083 maf would be the same during the 2024 to 2026 operating years. An increase in the allocated shortages above 2.083 maf, proposed for the 2025 and 2026 operating years, would result in additional short-term impacts on agriculture in Arizona, such as an increase in acres of fallowed field crops and acres of fallowed vegetables and other irrigated crops. Impacts would also affect a wider range of users and would extend to non-Indian croplands in Imperial and Riverside Counties in California. Economic impacts from production loss in Arizona would range from $82 million to $207 million in 2024 and will reach $257 million for the highest shortage volume. Economic impacts in California during 2025 and 2026 would range from $0 to $486 million.

Table 3-107
Acres of Fallowed Cropland and the Loss of Market Value of Agricultural Production in Arizona in 2024 – Action Alternative 1

Shortage Amount (1,000 af)	Non-Indian Agriculture		Indian Agriculture		Total Agriculture in the Study Area	
	Fallowed Cropland (Acres)	Change in Production Value	Fallowed Cropland (Acres)	Change in Production Value	Fallowed Cropland (Acres)	Change in Production Value
400	72,423	$82,222,615	0	$0	72,423	$82,222,615
1,066	86,993	$103,050,566	23,467	$37,286,299	110,460	$140,336,865
1,234	88,882	$105,978,210	30,162	$53,049,322	119,044	$159,027,532
1,734	106,671	$127,062,640	32,635	$59,962,276	139,306	$187,024,916
2,083	125,415	$146,618,873	32,635	$59,962,276	158,050	$206,581,149

Source: Values were calculated using input from the Shortage Allocation Model and crop profitability, according to the methodology described above.
Note: Modeling results should only be used to compare the relative magnitude of impacts that are reasonably expected to occur under the alternatives. The results are not a substitute for agricultural production loss estimates in the analysis area; the results are subject to uncertainties from built-in assumptions and data limitations.
For those Tribes identified by Reclamation to use the full or a substantial amount of their entitled water for agricultural operations, this analysis assumed 100 percent of consumptive-use water, as well as allocated shortages, were used for irrigation; the exact proportion of water used for agricultural operations for these Tribes was not known.

No agricultural impacts would occur to in the Nevada planning area during the 2025 and 2026 operating years.

Table 3-108 and Table 3-109 show the potential impacts on agriculture in terms of acres of fallowed field crops and loss of agricultural production during the 2025 and 2026 operating years, in Arizona and California, respectively, under Action Alternative 1.

Table 3-108
Acres of Fallowed Cropland and the Loss of Market Value of Agricultural Production in Arizona in 2025–2026 – Action Alternative 1

Shortage Amount (1,000 af)	Non-Indian Agriculture		Indian Agriculture		Total Agriculture in the Study Area	
	Fallowed Cropland (Acres)	Change in Production Value	Fallowed Cropland (Acres)	Change in Production Value	Fallowed Cropland (Acres)	Change in Production Value
400	72,423	$82,222,615	0	$0	72,423	$82,222,615
1,066	86,993	$103,050,566	23,467	$37,286,299	110,460	$140,336,865
1,234	88,882	$105,978,210	30,162	$53,049,322	119,044	$159,027,532
1,734	106,671	$127,062,640	32,635	$59,962,276	139,306	$187,024,916
2,083	125,415	$146,618,873	32,635	$59,962,276	158,050	$206,581,149
2,250	133,772	$155,351,557	32,635	$59,962,276	166,407	$215,313,833
2,500	145,883	$168,220,990	32,635	$59,962,276	178,518	$228,183,266
3,000	158,786	$192,018,523	32,635	$59,962,276	191,421	$251,980,799

Shortage Amount (1,000 af)	Non-Indian Agriculture		Indian Agriculture		Total Agriculture in the Study Area	
	Fallowed Cropland (Acres)	Change in Production Value	Fallowed Cropland (Acres)	Change in Production Value	Fallowed Cropland (Acres)	Change in Production Value
3,333	159,926	$193,766,405	32,635	$59,962,276	192,561	$253,728,681
3,667	160,935	$195,262,454	32,635	$59,962,276	193,570	$255,224,730
4,000	161,925	$196,731,353	32,635	$59,962,276	194,560	$256,693,629

Source: Values were calculated using input from the Shortage Allocation Model and crop profitability estimates, according to the methodology described above.

Note: Modeling results should only be used to compare the relative magnitude of impacts that are reasonably expected to occur under the alternatives. The results are not a substitute for agricultural production loss estimates in the analysis area; the results are subject to uncertainties from built-in assumptions and data limitations.

For those Tribes identified by Reclamation to use the full or a substantial amount of their entitled water for agricultural operations, this analysis assumed 100 percent of consumptive-use water, as well as allocated shortages, were used for irrigation; the exact proportion of water used for agricultural operations for these Tribes was not known.

Due to data limitations for Indian agriculture, such as those involving privacy concerns, particularly for Tribes where three or fewer farms for a given crop exist, estimates did not account for the full allocated shortage volumes. Therefore, economic impacts may be larger than the estimated values.

Table 3-109
Acres of Fallowed Cropland and the Loss of Market Value of Agricultural Production in California in 2025–2026 – Action Alternative 1

Shortage Amount (1,000 af)	Non-Indian Agriculture		Indian Agriculture		Total Agriculture in the Study Area	
	Fallowed Cropland (Acres)	Change in Production Value	Fallowed Cropland (Acres)	Change in Production Value	Fallowed Cropland (Acres)	Change in Production Value
400	0	$0	0	$0	0	$0
1,066	0	$0	0	$0	0	$0
1,234	0	$0	0	$0	0	$0
1,734	0	$0	0	$0	0	$0
2,083	0	$0	0	$0	0	$0
2,250	0	$0	0	$0	0	$0
2,500	16,911	$19,340,588	0	$0	16,911	$19,340,588
3,000	51,879	$73,913,147	0	$0	51,879	$73,913,147
3,333	74,832	$113,389,673	0	$0	74,832	$113,389,673
3,667	109,642	$166,323,981	0	$0	109,642	$166,323,981
4,000	175,586	$486,285,463	0	$0	175,586	$486,285,463

Source: Values were calculated using input from the Shortage Allocation Model and crop profitability estimates, according to the methodology described above.

Note: Modeling results should only be used to compare the relative magnitude of impacts that are reasonably expected to occur under the alternatives. The results are not a substitute for agricultural production loss estimates in the analysis area; the results are subject to uncertainties from built-in assumptions and data limitations.

For those Tribes identified by Reclamation to use the full or a substantial amount of their entitled water for agricultural operations, this analysis assumed 100 percent of consumptive-use water, as well as allocated shortages,

were used for irrigation; the exact proportion of water used for agricultural operations for these Tribes was not known.
Due to data limitations for Indian agriculture, such as those involving privacy concerns, particularly for Tribes where three or fewer farms for a given crop exist, estimates did not account for the full allocated shortage volumes. Therefore, economic impacts may be larger than the estimated values.

In the long term, operating guidelines consistent with Action Alternative 1 would be expected to reduce the potential for water levels to decline below a critical level in Lake Mead. This would reduce the potential long-term impacts on agriculture in fallowed crops and production loss, compared with the No Action Alternative.

Table 3-110 provides an overview of the jobs, income, and total economic output associated with the estimated changes in agricultural production value in 2024 under Action Alternative 1 for Arizona. **Table 3-111** provides an analysis for the changes in associated tax revenue for the same period. No shortages would occur in California or Nevada under this time period; therefore, no changes to contributions are modeled. Compared with the No Action Alternative, estimated jobs losses would increase from 1,613 to 3,122 at the highest shortage levels modeled, with the majority of the additional losses related to the additional fallowed crops in Indian Agriculture. Labor income and tax revenue changes would follow similar trends.

Table 3-110
Estimated Jobs and Income under Action Alternative 1 (2024) - Arizona

Shortage Amount (1,000 af)	Non-Indian Agriculture		Indian Agriculture		Total	
	Total Jobs	Total Income	Total Jobs	Total Income	Total Jobs	Total Income
400	1,060	$87,053,271	0	0	1,060	$87,053,271
1,066	1,411	$102,849,513	680	$25,188,393	2,091	$132,100,677
1,234	1,709	$111,317,293	1,104	$46,509,628	2,594	$144,699,734
1,734	1,863	$115,102,728	1,249	$47,932,919	2,957	$156,474,153
2,083	1,933	$116,802,486	1,249	$47,932,919	3,112	$160,259,588

Source: Agricultural model output and IMPLAN 2021 software and data
Note: Total jobs include direct, indirect, and induced jobs. Due to model limitations and market uncertainties, modeling results should only be used to compare the relative magnitude of impacts that are reasonably expected to occur under the alternative.

Table 3-111
Estimated Tax Revenue Change under Action Alternative 1 (2024)

Shortage Amount (1,000 af)	Non-Indian Agriculture	Indian Agriculture
400	$14,628,722	$0
1,066	$17,924,854	$5,337,194
1,234	$18,452,931	$7,182,153
1,734	$222,541,934	$8,394,585
2,083	$22,702,247	$8,394,585

Source: Agricultural model output and IMPLAN 2021 software and data
Note: Total includes local, state, and federal tax revenue. Tax amounts are

impacted by agricultural subsidies. The agriculture Sectors in IMPLAN see significant amounts of government subsidies. Because tax revenue is net of subsidies, it can be negative for a given industry in a given year, if that industry received more subsidies from the government than it paid out in these specific taxes in that year. Due to model limitations and market uncertainties, modeling results should only be used to compare the relative magnitude of impacts that are reasonably expected to occur under the alternative.

Table 3-112 and **Table 3-113** provide an overview of the jobs, income, and total economic output associated with the estimated changes in the agricultural production value in 2025–2026 estimated shortage levels under Action Alternative 1 for Arizona and California respectively. **Table 3-114** provides an analysis for the changes in associated tax revenue for the same period. Although changes are to agricultural revenue are projected for Nevada in Action Alternative 1 for 2025–2026, changes to economic contributions are not modeled here or under any alternative. This is because shortages would impact only one Tribal entity and are therefore not anticipated to result in substantial regional economic impacts. Because the No Action Alternative modeled shortages did not exceed 1.100 maf/year, and shortages examined for 2025/2026 under Action Alternative 1 include levels up to 4.000 maf/year, acres of fallowed crops and related losses in jobs, income, and tax revenue are substantially higher under Action Alternative 1 as compared to the No Action Alternative. At the highest shortage level, as many as 7,078 jobs and as much as $452 million in labor income in Arizona may be reduced due to reduced agricultural projection. In addition, at the higher shortage levels under Action Alternative 1 in 2025–2026, shortages are also anticipated to occur in California. A total of up to 2,924 jobs and $185 million in labor income could be impacted in this state under the 4.000-maf shortage level. Tax revenue reduction would follow similar trends.

Table 3-112
Estimated Jobs and Income under Action Alternative 1 (2025–2026) - Arizona

Shortage Amount (1,000 af)	Non-Indian Agriculture		Indian Agriculture		Total	
	Total Jobs	Total Income	Total Jobs	Total Income	Total Jobs	Total Income
400	1,060	$87,053,271	0	$0	1,060	$87,053,271
1,066	1,411	$102,849,513	680	$29,251,164	2,091	$132,100,677
1,234	1,490	$104,977,434	1,104	$39,722,300	2,594	$144,699,734
1,734	1,709	$111,317,293	1,249	$45,156,860	2,957	$156,474,153
2,083	1,863	$115,102,728	1,249	$45,156,860	3,112	$160,259,588
2,250	1,933	$116,802,486	1,249	$45,156,860	3,182	$161,959,346
2,500	2,032	$119,199,304	1,249	$45,156,860	3,280	$164,356,164
3,000	2,180	$122,819,752	1,249	$45,156,860	3,429	$167,976,612
3,333	3,929	$260,639,745	1,249	$45,156,860	5,178	$305,796,606
3,667	4,863	$333,964,166	1,249	$45,156,860	6,111	$379,121,026
4,000	5,829	$407,048,234	1,249	$45,156,860	7,078	$452,205,094

Source: Agricultural model output and IMPLAN 2021 software and data
Note: Total jobs include direct, indirect, and induced jobs. Due to model limitations and market uncertainties, modeling results should only be used to compare the relative magnitude of impacts that are reasonably expected to occur under the alternative.

Table 3-113
Estimated Jobs and Income under Action Alternative 1 (2025–2026) - California

Shortage Amount (1,000 af)	Non-Indian Agriculture		Indian Agriculture		Total	
	Total Jobs	Total Income	Total Jobs	Total Income	Total Jobs	Total Income
400	0	0	0	0	0	0
1,066	0	0	0	0	0	0
1,234	0	0	0	0	0	0
1,734	0	0	0	0	0	0
2,083	0	0	0	0	0	0
2,250	0	0	0	0	0	0
2,500	89	$7,825,785	0	0	89	$7,825,785
3,000	493	$34,244,689	0	0	493	$34,244,689
3,333	780	$53,682,957	0	0	780	$53,682,957
3,667	1,072	$70,821,791	0	0	1,072	$70,821,791
4,000	2,924	$185,271,092	0	0	2,924	$185,271,092

Source: Agricultural model output and IMPLAN 2021 software and data
Note: Total jobs include direct, indirect, and induced jobs. Due to model limitations and market uncertainties, modeling results should only be used to compare the relative magnitude of impacts that are reasonably expected to occur under the alternative.

Table 3-114
Estimated Tax Revenue Change under Action Alternative 1 (2025–2026)

Shortage Amount	Non-Indian Agriculture		Indian Agriculture[1]
(1,000 af)	TotalAZ	TotalCA	TotalAZ
400	$14,628,722	0	0
1,066	$17,924,853	0	$5,337,194
1,234	$18,452,931	0	$7,182,153
1,734	$22,541,934	0	$8,394,585
2,083	$22,702,247	0	$8,394,585
2,250	$22,769,737	0	$8,394,585
2,500	$22,948,577	$3,711,572	$8,394,585
3,000	$27,136,249	$11,265,481	$8,394,585
3,333	$45,844,786	$17,850,058	$8,394,585
3,667	$64,891,936	$22,975,677	$8,394,585
4,000	$83,878,460	$66,229,271	$8,394,585

Source: Agricultural model output and IMPLAN 2021 software and data
[1] No Indian Agriculture contribution changes in California under Action Alternative 1
Note: Total includes local, state, and federal tax revenue. Tax amounts are impacted by agricultural subsidies. The agriculture Sectors in IMPLAN see significant amounts of government subsidies. Because tax revenue is net of subsidies, it can be negative for a given industry in a given year, if that industry received more subsidies from the government than it paid out in these specific taxes in that year. Due to model limitations and market uncertainties, modeling results should only be used to compare the relative magnitude of impacts that are reasonably expected to occur under the alternative.

Action Alternative 2

The total volume of allocated shortages is the same under both action alternatives; however, under Action Alternative 2, shortages are distributed among users and across the study area, rather than according to the priority system as under Action Alternative 1. The total area of fallowed lands would likely be similar under both action alternatives; however, the distribution of impacts across the study area would include a wider range of users for all shortage volumes.

Indian and Non-Indian agriculture in Imperial, Riverside, and San Bernardino Counties, California, as well as Indian agriculture in Clark County, Nevada would experience impacts for operating years 2024 to 2026 under Action Alternative 2. In 2024, economic impacts from production loss would range from $78 million to $179 million in Arizona, from $23 million to $132 million in California, and from $23,000 to $146,000 in Nevada. In 2025 and 2026, economic loss would reach $264 million in Arizona, $338 million in California, and $316,000 in Nevada. **Table 3-115**, **Table 3-116**, and **Table 3-117** show the total estimated acres of fallowed cropland and the reduction in market value of agricultural production in Arizona, California, and Nevada, respectively, for different shortage amounts in 2024, under Action Alternative 2.

Table 3-115
Acres of Fallowed Cropland and the Loss of Market Value of Agricultural Production in Arizona in 2024 – Action Alternative 2

Shortage Amount (1,000 af)	Non-Indian		Indian Agriculture		Total Agriculture in the Study Area	
	Fallowed Cropland (Acres)	Change in Production Value	Fallowed Cropland (Acres)	Change in Production Value	Fallowed Cropland (Acres)	Change in Production Value
400	66,615	$75,833,745	1,835	$2,695,839	68,450	$78,529,584
1,066	97,254	$112,326,161	9,907	$13,441,250	107,161	$125,767,411
1,234	99,729	$114,733,093	16,153	$23,020,765	115,882	$137,753,858
1,734	108,257	$123,620,834	29,363	$45,485,161	137,620	$169,105,995
2,083[1]	111,195	$126,248,174	28,400	$44,020,448	139,595	$170,268,622
2,083[2]	116,758	$131,767,250	30,142	$47,003,029	146,900	$178,770,279

Source: Values were calculated using input from the Shortage Allocation Model and crop profitability estimates, according to the methodology described above.
[1]Indicates 13.11-percent reduction to each water user's 2021 adjusted consumptive use.
[2]Indicates 15.55-percent reduction to each water user's 2021 adjusted consumptive use.
Note: Modeling results should only be used to compare the relative magnitude of impacts that are reasonably expected to occur under the alternatives. The results are not a substitute for agricultural production loss estimates in the analysis area; the results are subject to uncertainties from built-in assumptions and data limitations.
For those Tribes identified by Reclamation to use the full or a substantial amount of their entitled water for agricultural operations, this analysis assumed 100 percent of consumptive-use water, as well as allocated shortages, were used for irrigation; the exact proportion of water used for agricultural operations for these Tribes was not known.
Due to data limitations for Indian agriculture, such as those involving privacy concerns, particularly for Tribes where three or fewer farms for a given crop exist, estimates did not account for the full allocated shortage volumes. Therefore, economic impacts may be larger than the estimated values.

Table 3-116
Acres of Fallowed Cropland and the Loss of Market Value of Agricultural Production in California in 2024 – Action Alternative 2

Shortage Amount (1,000 af)	Non-Indian		Indian Agriculture		Total Agriculture in the Study Area	
	Fallowed Cropland (Acres)	Change in Production Value	Fallowed Cropland (Acres)	Change in Production Value	Fallowed Cropland (Acres)	Change in Production Value
400	18,946	$22,548,853	39	$35,089	18,985	$22,583,942
1,066	43,604	$59,692,441	105	$93,512	43,709	$59,785,953
1,234	49,499	$69,251,638	121	$108,249	49,620	$69,359,887
1,734	67,044	$97,701,630	198	$186,024	67,242	$97,887,654
2,083[1]	75,185	$110,902,426	245	$229,062	75,430	$111,131,488
2,083[2]	88,027	$131,727,792	277	$256,755	88,304	$131,984,547

Source: Values were calculated using input from the Shortage Allocation Model and crop profitability estimates, according to the methodology described above.
[1]Indicates 13.11-percent reduction to each water user's 2021 adjusted consumptive use.
[2]Indicates 15.55-percent reduction to each water user's 2021 adjusted consumptive use.
Note: Modeling results should only be used to compare the relative magnitude of impacts that are reasonably expected to occur under the alternatives. The results are not a substitute for agricultural production loss estimates in the analysis area; the results are subject to uncertainties from built-in assumptions and data limitations.
For those Tribes identified by Reclamation to use the full or a substantial amount of their entitled water for agricultural operations, this analysis assumed 100 percent of consumptive-use water, as well as allocated shortages, were used for irrigation; the exact proportion of water used for agricultural operations for these Tribes was not known.
Due to data limitations for Indian agriculture, such as those involving privacy concerns, particularly for Tribes where three or fewer farms for a given crop exist, estimates did not account for the full allocated shortage volumes. Therefore, economic impacts may be larger than the estimated values.

Table 3-117
Acres of Fallowed Cropland and the Loss of Market Value of Agricultural Production in Nevada in 2024 – Action Alternative 2

Shortage Amount (1,000 af)	Non-Indian		Indian Agriculture		Total Agriculture in the Study Area	
	Fallowed Cropland (Acres)	Change in Production Value	Fallowed Cropland (Acres)	Change in Production Value	Fallowed Cropland (Acres)	Change in Production Value
400	0	$0	19	$22,882	19	$22,882
1,066	0	$0	51	$60,980	51	$60,980
1,234	0	$0	59	$70,591	59	$70,591
1,734	0	$0	96	$112,286	96	$112,286
2,083[1]	0	$0	119	$132,821	119	$132,821
2,083[2]	0	$0	133	$145,949	133	$145,949

Source: Values were calculated using input from the Shortage Allocation Model and crop profitability estimates, according to the methodology described above.
[1]Indicates 13.11-percent reduction to each water user's 2021 adjusted consumptive use.
[2]Indicates 15.55-percent reduction to each water user's 2021 adjusted consumptive use.
Note: Modeling results should only be used to compare the relative magnitude of impacts that are reasonably expected to occur under the alternatives. The results are not a substitute for agricultural production loss estimates in the analysis area; the results are subject to uncertainties from built-in assumptions and data limitations.
For those Tribes identified by Reclamation to use the full or a substantial amount of their entitled water for agricultural operations, this analysis assumed 100 percent of consumptive-use water, as well as allocated shortages, were used for irrigation; the exact proportion of water used for agricultural operations for these Tribes was not known.
Due to data limitations for Indian agriculture, such as those involving privacy concerns, particularly for Tribes where three or fewer farms for a given crop exist, estimates did not account for the full allocated shortage volumes. Therefore, economic impacts may be larger than the estimated values.

Table 3-118, **Table 3-119**, and **Table 3-120** show potential impacts on agriculture in terms of fallowed field crops and agricultural production loss for the 2025–2026 period, for the Arizona, California, and Nevada planning area, respectively, under Action Alternative 2.

Table 3-118
Acres of Fallowed Cropland and the Loss of Market Value of Agricultural Production in Arizona in 2025–2026 – Action Alternative 2

Shortage Amount (1,000 af)	Non-Indian Agriculture			Indian Agriculture		Total Agriculture in the Study Area
	Fallowed Cropland (Acres)	Change in Production Value	Fallowed Cropland (Acres)	Change in Production Value	Fallowed Cropland (Acres)	Change in Production Value
400	66,615	$75,833,745	1,835	$2,695,839	68,450	$78,529,584
1,066	97,254	$112,326,161	9,907	$13,441,250	107,161	$125,767,411
1,234	99,729	$114,733,093	16,153	$23,020,765	115,882	$137,753,858

Shortage Amount (1,000 af)	Non-Indian Agriculture			Indian Agriculture		Total Agriculture in the Study Area
	Fallowed Cropland (Acres)	Change in Production Value	Fallowed Cropland (Acres)	Change in Production Value	Fallowed Cropland (Acres)	Change in Production Value
1,734	108,257	$123,620,834	29,363	$45,485,161	137,620	$169,105,995
2,083[1]	111,195	$126,248,174	28,400	$44,020,448	139,595	$170,268,622
2,083[2]	116,758	$131,767,250	30,142	$47,003,029	146,900	$178,770,279
2,250	121,515	$137,075,698	30,142	$47,003,029	151,657	$184,078,727
2,500	126,587	$141,613,184	33,649	$53,489,195	160,236	$195,102,379
3,000	136,280	$154,887,139	43,694	$75,492,535	179,974	$230,379,674
3,333	140,046	$162,601,480	46,627	$82,969,504	186,673	$245,570,984
3,667	144,167	$170,101,915	49,109	$87,625,317	193,276	$257,727,232
4,000	145,368	$171,964,873	51,585	$92,270,321	196,953	$264,235,194

Source: Values were calculated using input from the Shortage Allocation Model and crop profitability estimates, according to the methodology described above.

[1]Indicates 13.11-percent reduction to each water user's 2021 adjusted consumptive use.

[2]Indicates 15.55-percent reduction to each water user's 2021 adjusted consumptive use.

Note: Modeling results should only be used to compare the relative magnitude of impacts that are reasonably expected to occur under the alternatives. The results are not a substitute for agricultural production loss estimates in the analysis area; the results are subject to uncertainties from built-in assumptions and data limitations.

For those Tribes identified by Reclamation to use the full or a substantial amount of their entitled water for agricultural operations, this analysis assumed 100 percent of consumptive-use water, as well as allocated shortages, were used for irrigation; the exact proportion of water used for agricultural operations for these Tribes was not known.

Due to data limitations for Indian agriculture, such as those involving privacy concerns, particularly for Tribes where three or fewer farms for a given crop exist, estimates did not account for the full allocated shortage volumes. Therefore, economic impacts may be larger than the estimated values.

Table 3-119
Acres of Fallowed Cropland and the Loss of Market Value of Agricultural Production in California in 2025–2026 – Action Alternative 2

Shortage Amount (1,000 af)	Non-Indian Agriculture		Indian Agriculture		Total Agriculture in the Study Area	
	Fallowed Cropland (Acres)	Change in Production Value	Fallowed Cropland (Acres)	Change in Production Value	Fallowed Cropland (Acres)	Change in Production Value
400	18,946	$22,548,853	39	$35,089	18,985	$22,583,942
1,066	43,604	$59,692,441	105	$93,512	43,709	$59,785,953
1,234	49,499	$69,251,638	121	$108,249	49,620	$69,359,887
1,734	67,044	$97,701,630	198	$186,024	67,242	$97,887,654
2,083[1]	75,185	$110,902,426	245	$229,062	75,430	$111,131,488
2,083[2]	88,027	$131,727,792	277	$256,755	88,304	$131,984,547
2,250	96,238	$145,042,417	277	$256,755	96,515	$145,299,172
2,500	110,274	$167,802,411	332	$304,094	110,606	$168,106,505

Shortage Amount (1,000 af)	Non-Indian Agriculture		Indian Agriculture		Total Agriculture in the Study Area	
	Fallowed Cropland (Acres)	Change in Production Value	Fallowed Cropland (Acres)	Change in Production Value	Fallowed Cropland (Acres)	Change in Production Value
3,000	139,539	$215,256,997	446	$402,795	139,985	$215,659,792
3,333	163,250	$255,060,133	537	$481,614	163,787	$255,541,747
3,667	187,422	$297,160,257	628	$560,670	188,050	$297,720,927
4,000	213,571	$337,812,785	718	$639,511	214,289	$338,452,296

Source: Values were calculated using input from the Shortage Allocation Model and crop profitability estimates, according to the methodology described above.
[1]Indicates 13.11-percent reduction to each water user's 2021 adjusted consumptive use.
[2]Indicates 15.55-percent reduction to each water user's 2021 adjusted consumptive use.
Note: Modeling results should only be used to compare the relative magnitude of impacts that are reasonably expected to occur under the alternatives. The results are not a substitute for agricultural production loss estimates in the analysis area; the results are subject to uncertainties from built-in assumptions and data limitations.
For those Tribes identified by Reclamation to use the full or a substantial amount of their entitled water for agricultural operations, this analysis assumed 100 percent of consumptive-use water, as well as allocated shortages, were used for irrigation; the exact proportion of water used for agricultural operations for these Tribes was not known.
Due to data limitations for Indian agriculture, such as those involving privacy concerns, particularly for Tribes where three or fewer farms for a given crop exist, estimates did not account for the full allocated shortage volumes. Therefore, economic impacts may be larger than the estimated values.

Table 3-120
Acres of Fallowed Cropland and the Loss of Market Value of Agricultural Production in Nevada in 2025–2026 – Action Alternative 2

Shortage Amount (1,000 af)	Non-Indian Agriculture		Indian Agriculture		Total Agriculture in the Study Area	
	Fallowed Cropland (Acres)	Change in Production Value	Fallowed Cropland (Acres)	Change in Production Value	Fallowed Cropland (Acres)	Change in Production Value
400	0	$0	19	$22,882	19	$22,882
1,066	0	$0	51	$60,980	51	$60,980
1,234	0	$0	59	$70,591	59	$70,591
1,734	0	$0	96	$112,286	96	$112,286
2,083[1]	0	$0	119	$132,821	119	$132,821
2,083[2]	0	$0	133	$145,949	133	$145,949
2,250	0	$0	133	$145,949	133	$145,949
2,500	0	$0	158	$168,391	158	$168,391
3,000	0	$0	197	$213,381	197	$213,381
3,333	0	$0	216	$247,686	216	$247,686
3,667	0	$0	235	$282,094	235	$282,094
4,000	0	$0	254	$316,398	254	$316,398

Source: Values were calculated using input from the Shortage Allocation Model and crop profitability estimates, according to the methodology described above.

[1]Indicates 13.11-percent reduction to each water user's 2021 adjusted consumptive use.
[2]Indicates 15.55-percent reduction to each water user's 2021 adjusted consumptive use.
Note: Modeling results should only be used to compare the relative magnitude of impacts that are reasonably expected to occur under the alternatives. The results are not a substitute for agricultural production loss estimates in the analysis area; the results are subject to uncertainties from built-in assumptions and data limitations.
For those Tribes identified by Reclamation to use the full or a substantial amount of their entitled water for agricultural operations, this analysis assumed 100 percent of consumptive-use water, as well as allocated shortages, were used for irrigation; the exact proportion of water used for agricultural operations for these Tribes was not known.
Due to data limitations for Indian agriculture, such as those involving privacy concerns, particularly for Tribes where three or fewer farms for a given crop exist, estimates did not account for the full allocated shortage volumes. Therefore, economic impacts may be larger than the estimated values.

Table 3-121 provides an overview of the jobs, income, and total economic output associated with the estimated changes in agricultural production value in 2024 under Action Alternative 2 in Arizona. California data are provided in **Table 3-122**. **Table 3-123** provides an analysis for changes in the associated tax revenue for the same period. For the 2.083-maf shortage level, a high and low estimate are provided, based on a range of different water releases possible under this modeling scenario, dependent on the reservoir elevation in Lake Mead. Compared with the No Action Alternative, impacts on water users in Arizona would be increased. An estimated total of 2,163 jobs and $164 million in labor income would be impacted by reduced agricultural production in Arizona at shortages up to 2.083 maf, compared with a total of 1,613 jobs and $108 million in losses under the No Action Alternative in Arizona. Action Alternative 2 would also result in increased impacts on jobs and income in California at shortage levels modeled for 2024. Under the No Action Alternative, no impacts would be anticipated to agricultural users in California. Under Action Alternative 2, an estimated 912 jobs and $662 million in labor income would be impacted under the 2.083-maf shortage level. Similar trends would be seen in tax revenue.

Table 3-124 provides an overview of the jobs, income, and total economic output associated with the estimated changes in agricultural production value in 2025–2026 estimated shortage levels under Action Alternative 2. California data are provided in **Table 3-125**. **Table 3-126** provides an analysis for the changes in associated tax revenue for the same period. As noted, under Action Alternative 1, shortage levels modeled under action alternatives exceed those examined in the No Action Alternative; therefore, the anticipated impacts on agricultural production losses and related economic contributions are higher under the action alternatives. For the 4.000-maf shortage level, an estimated total of 4,410 jobs and $290 million in labor income would be impacted by reduced agricultural production in Arizona, compared with a total of 1,613 and $108 million in losses under the No Action Alternative in Arizona. Action Alternative 2 would result in increased impacts on jobs and income in California. Under the No Action Alternative, no impacts would be anticipated to agricultural users in California. Under Action Alternative 2, an estimated 2,439 jobs and $165 million in labor income would be impacted under the 4.000 maf shortage level. Similar trends would be seen in tax revenue.

Table 3-121
Estimated Jobs and Income under Action Alternative 2 (2024) - Arizona

Shortage Amount (1,000 af)	Non-Indian Agriculture		Indian Agriculture		Total	
	Total Jobs	Total Income	Total Jobs	Total Income	Total Jobs	Total Income
400	871	$79,524,394	18	$1,983,822	889	$81,508,217
1,066	1,392	$112,751,059	113	$11,049,422	1,505	123,800,489
1,234	1,415	$115,045,717	245	$18,005,232	1,660	133,050,948
1,734	1,549	$123,457,795	423	$27,116,487	1,972	150,574,283
2,083 (low)	1,555	$125,976,723	609	$34,672,186	2,163	160,648,909
2,083 (high)	1,616	$131,212,498	546	$33,268,885	2,163	164,481,382

Source: Agricultural model output and IMPLAN 2021 software and data
Note: Total jobs include direct, indirect, and induced jobs. Due to model limitations and market uncertainties, modeling results should only be used to compare the relative magnitude of impacts that are reasonably expected to occur under the alternative.

Table 3-122
Estimated Jobs and Income under Action Alternative 2 (2024) - California

Shortage Amount (1,000 af)	Non-Indian Agriculture		Indian Agriculture		Total	
	Total Jobs	Total Income	Total Jobs	Total Income	Total Jobs	Total Income
400	110	$8,573,019	0	$12,342	110	$8,585,362
1,066	370	$27,324,493	0	$32,893	370	$27,357,386
1,234	442	$32,038,008	0	$38,076	442	$32,076,084
1,734	656	$46,065,776	0	$61,554	656	$46,127,330
2,083 (low)	755	$52,575,464	1	$76,057	756	$52,651,521
2,083 (high)	912	$62,841,129	1	$89,008	912	$62,930,137

Source: Agricultural model output and IMPLAN 2021 software and data
Note: Total jobs include direct, indirect, and induced jobs. Due to model limitations and market uncertainties, modeling results should only be used to compare the relative magnitude of impacts that are reasonably expected to occur under the alternative.

Table 3-123
Estimated Tax Revenue Change under Action Alternative 2 (2024)

Shortage Amount (1,000 af)	Non-Indian Agriculture		Indian Agriculture	
	Total AZ	Total CA	Total AZ	Total CA
400	$14,441,786	$3,320,768	$451,002	$4,695
1,066	$18,920,153	$9,954,879	$2,094,427	$12,511
1,234	$18,849,730	$11,659,670	$3,217,611	$14,483
1,734	$18,913,577	$16,733,262	$5,103,649	$22,378
2,083 (low)	$18,702,085	$19,087,692	$6,356,835	$26,950
2,083 (high)	$18,586,552	$22,800,519	$6,193,748	$31,349

Source: Agricultural model output and IMPLAN 2021 software and data
Note: Total includes local, state, and federal tax revenue. Tax amounts are impacted by agricultural subsidies. The agriculture Sectors in IMPLAN see significant amounts of government subsidies. Because tax revenue is net of subsidies, it can be negative for a given industry in a given year, if that industry received more subsidies from the government than it paid out in these specific taxes in that year. Due to model limitations and market uncertainties, modeling results should only be used to compare the relative magnitude of impacts that are reasonably expected to occur under the alternative.

Table 3-124
Estimated Jobs and Income under Action Alternative 2 (2025–2026) - Arizona

Shortage Amount (1,000 af)	Non-Indian Agriculture		Indian Agriculture		Total	
	Total Jobs	Total Income	Total Jobs	Total Income	Total Jobs	Total Income
400	871	$79,524,394	18	$1,983,822	889	$81,508,217
1,066	1,392	$112,751,059	113	$11,049,422	1,505	$123,800,481
1,234	1,415	$115,045,717	245	$18,005,232	1,660	$133,050,948
1,734	1,415	$115,045,717	423	$27,116,487	1,838	$142,162,204
2,083 (low)	1,555	$125,976,723	609	$34,672,186	2,164	$160,648,909
2,083 (high)	1,616	$131,212,498	546	$33,268,885	2,163	$164,481,382
2,250	1,723	$136,194,407	583	$35,152,248	2,306	$171,346,654
2,500	1,555	$125,976,723	730	$39,466,014	2,285	$165,442,737
3,000	1,947	$152,247,351	1,239	$53,613,367	3,186	$205,860,719
3,333	2,037	$158,432,980	1,314	$57,881,909	3,351	$216,314,889
3,667	2,387	$180,686,106	1,364	$60,859,943	3,751	$241,546,049
4,000	2,995	$226,174,042	1,415	$63,832,236	4,410	$290,006,278

Source: Agricultural model output and IMPLAN 2021 software and data
Note: Total jobs include direct, indirect, and induced jobs. Due to model limitations and market uncertainties, modeling results should only be used to compare the relative magnitude of impacts that are reasonably expected to occur under the alternative.

Table 3-125
Estimated Jobs and Income under Action Alternative 2 (2025–2026) - California

Shortage Amount (1,000 af)	Non-Indian Agriculture		Indian Agriculture		Total	
	Total Jobs	Total Income	Total Jobs	Total Income	Total Jobs	Total Income
400	110	$8,573,019	0	$12,342	110	$8,585,362
1,066	370	$27,324,493	0	$32,893	370	$27,357,386
1,234	442	$32,038,008	0	$38,076	442	$32,076,084
1,734	656	$46,065,776	0	$61,554	656	$46,127,330
2,083 (low)	755	$52,575,464	1	$76,057	756	$52,651,521
2,083 (high)	912	$62,841,129	1	$89,008	912	$62,930,137
2,250	1,012	$69,409,445	1	$94,861	1,012	$69,504,305
2,500	1,183	$80,632,098	1	$104,864	1,183	$80,736,963
3,000	1,539	$104,031,331	1	$125,722	1,540	$104,157,054
3,333	1,827	$123,667,535	1	$142,379	1,828	$123,809,913
3,667	2,120	$144,447,567	1	$159,085	2,121	$144,606,652
4,000	2,438	$164,501,613	1	$175,650	2,439	$164,677,263

Source: Agricultural model output and IMPLAN 2021 software and data
Note: Total jobs include direct, indirect, and induced jobs. Due to model limitations and market uncertainties, modeling results should only be used to compare the relative magnitude of impacts that are reasonably expected to occur under the alternative.

Table 3-126
Estimated Tax Revenue Change under Action Alternative 2 (2025–2026)

Shortage Amount (1,000 af)	Non-Indian Agriculture		Indian Agriculture	
	Total AZ	Total CA	Total AZ	Total CA
400	$14,441,786	$3,320,768	$451,002	$4,695
1,066	$18,920,153	$9,954,879	$2,094,427	$12,511
1,234	$18,849,730	$11,659,670	$3,217,611	$14,483
1,734	$18,913,577	$16,733,262	$5,103,649	$22,378
2,083 (low)	$18,702,085	$19,087,692	$6,356,835	$26,950
2,083 (high)	$18,586,552	$22,800,519	$6,193,748	$31,349
2,250	$18,795,183	$25,176,234	$6,516,527	$33,474
2,500	$18,431,747	$29,235,262	$7,260,834	$37,105
3,000	$19,721,923	$37,698,335	$9,807,362	$44,677
3,333	$21,141,410	$52,329,140	$10,748,976	$50,723
3,667	$26,630,213	$52,329,140	$11,372,762	$56,787
4,000	$38,388,829	$59,573,111	$11,995,366	$62,799

Source: Agricultural model output and IMPLAN 2021 software and data
Note: Total includes local, state, and federal tax revenue. Tax amounts are impacted by agricultural subsidies. The agriculture Sectors in IMPLAN see significant amounts of government subsidies. Because tax revenue is net of subsidies, it can be negative for a given industry in a given year, if that industry received more subsidies from the government than it paid out in these specific taxes in that year. Due to model limitations and market uncertainties, modeling results should only be used to compare the relative magnitude of impacts that are reasonably expected to occur under the alternative.

Cumulative Effects

The potential operational changes included in the Glen Canyon Dam/Smallmouth Bass flow options would not result in changes to water diversion amounts, water available for agriculture, or associated economic contributions.

Issue 2: How would changes to reservoir levels as a result of water shortages impact economic activity associated with recreation?

Summary

Under all alternatives, economic contributions from recreation in Lake Powell, Mead, and river-based recreation as well as adjacent land-based recreation would continue. Due to anticipated reservoir levels, there is potential for reduced contributions from reservoir-based recreation due to inaccessibility of boat launches in Lakes Powell and Mead as well as navigational issues. These issues would be present in all alternatives. For river-based recreation, activities and associated economic contributions and non-market values would be supported for all alternatives due to minimum flow requirements. Net economic value for whitewater rafting and anglers as a function of river flow would be similar across alternatives, with a slight decrease under Action Alternative 1.

No Action Alternative

Under the No Action Alternative, water levels in Lake Powell would remain below thresholds for boat launching, as discussed in **Section 3.1.4**; this would impact the visitor experience for recreational boating in the reservoir. At LMNRA and GCNRA, the No Action Alternative would make boat ramps and marina services partially or completely unavailable, limiting recreation activities and associated contributions and representing costs associated with maintaining access. Concessioners have spent $6 million in the last 3 years on projects directly tied to mitigating the impacts of low Lake Powell elevations (NPS 2022e).

The degree to which water levels would result in a reduction in economic contributions would depend on the impact on total visitation and related spending; these are difficult to predict given that water-based recreation is only one source of recreation-related economic contributions. Water-based recreation does, however, represents a large portion of visitor activity. Based on the most recent GCNRA visitor survey, 46 percent of visitors to the GCNRA participated in some form of motorized boating activity (NPS 2018). Water-based recreation is likely to be affected by lake volume.

Nehr et al. (2013) found lake volume in Lake Powell to be predictor of visitation levels in the summer season. This model projected that a 100,000-af increase in Lake Powell volume over a year was associated with 5,280 additional recreational visits to Lake Powell and $374,000 in additional visitor spending in tourism-related sectors in Coconino County, Arizona. The Lake Powell volume-visitation and volume-spending models imply the average visitor to Lake Powell spends $71 in lodging, restaurant and bar, and amusement/recreation sectors in Coconino County. This estimate is generally consistent with independent estimates of visitor spending derived from prior NPS visitor surveys (Nehr 2013). Based on correlation in Nehr 2013, it was estimated that lake elevation reductions from 3,675 to 3,625 feet would result in a more than 25 percent reduction in visitation (Johnson et al. 2016). As discussed in **Section 3.14.2**, the importance of land-based recreation may be increasing with decreasing lake elevations, which could influence total reductions in economic contributions in circumstances with decreased water levels.

For Lake Mead, a similar potential for a reduction in economic contributions associated with water-based recreation is possible; this is because all but one boat launch would be inaccessible under modeled reservoir levels under this alternative. Navigational hazards would also be present, further impacting the visitor experience and potentially the level of spending ($327 million in 2021, as detailed in the affected environment section).

The availability of camping near the lakeshore during the shoulder seasons increases revenue for gateway businesses and LMNRA since the fall and spring months are the best times of year for fishing. This effectively extends the season for visitation at the park, which makes revenue streams more stable for tourist-dependent businesses over a greater part of the year. As access to the shoreline changes, campers attracted for fishing opportunities may be discouraged from visiting, thus reducing income to the park and local businesses.

The loss of visitation and associated visitor spending associated with low lake levels could have significant impacts on the revenue associated with LMNRA and GCNRA, including declines in entry and camping fees, as well as impacts on concessioners due to declining visitation and commercial use fees. If operations are no longer economically viable, some concessionaires and small businesses may no longer be able to operate. This, in turn, could result in a loss of visitor services provided by concessionaries, including but not limited to, lodging, food and beverage facilities, fuel boat tours, and a medical clinic. A loss of these services can impact the visitor experience in opportunities available, as well as travel time and visitor safety. The economies of gateway communities could be significantly impacted from a loss of direct visitor spending and the associated indirect and induced spending.

For river-based recreation, commercial recreation upstream of Lake Powell may continue at present levels for the No Action Alternative and both action alternatives. High variability of flow has and will continue to make this section of the river less popular for commercial operation.

For whitewater rafting from Glen Canyon to Lake Mead, including GCNP, it is anticipated that minimum flow requirements for Glen Canyon Dam would result in continued commercial operations. As a result, it is anticipated that economic contributions would continue to be supported under the No Action Alternative; however, variation in flow may impact the recreational experience and the related value that users obtain from this experience.

The net economic value supported for whitewater rafting and anglers in Glen and Grand Canyons is shown in **Table 3-127**. It should be noted that the modeling estimates for all alternatives are based on flow and do not account for other factors that may impact boating or anglers. For example, in terms of fishing opportunities, under the No Action Alternative, there is the potential for seasonal impacts on rainbow trout from temperatures at lower lake elevations in Lake Powell (see **Section 3.14.2** for additional details).

Table 3-127
Mean High - Low Annual Net Economic Value for River-Based Recreation in Glen and Grand Canyon by Alternative (Millions of $2022)

Activity	Alternative		
	No Action	Action Alternative 1	Action Alternative 2
Whitewater rafting	24.57–38.37	21.52–38.46	23.56–38.49
Anglers	1.30–1.71	1.06–1.57	1.25–1.69

Note: Use values are based methods in Gaston et al. (2015). Mean annual high and low values based on high and low values by month from 90 ESP traces, with values provided for 60-month simulation period. Estimated individual whitewater trips per month (NPS 2006) are multiplied by the net economic value per trip to obtain the aggregate net economic value for whitewater rafting. Analysis does not include reservoir use, water-based day use in Glen Canyon, and recreational rafting in the lower Grand Canyon below Diamond Creek. Net economic value is indexed to 2022 dollars using the consumer pricing index (US Bureau of Labor Statistics 2023). This information represents estimates based on best available data and should be utilized for the purposed of alternative comparison only

Impacts on the visitor experience and level of visitation for commercial whitewater rafting have the potential to impact the associated economic contributions, which are important for rural communities and small business in northern Arizona and southern Utah, as discussed in the affected environment section.

Action Alternative 1

Impacts on economic contributions associated with water-based recreation on Lake Powell would be as described under the No Action Alternative, as boat launches would remain inaccessible.

For Lake Mead, a slight improvement to boat launch facilities may be seen for upper estimates of reservoir levels in 2026. However, overall impacts would be similar to those described under the No Action Alternative, with limits on accessibility and navigation and resulting impacts on economic contributions from water-based recreation.

For river-based recreation, impacts on the net economic value from flow changes would be similar to those described under the No Action Alternative. Modeling scenarios indicate a slight decrease in the lower range in net economic values as result of lower flow under some traces for whitewater rafting. For anglers, the net economic value based on river flow would be slightly reduced as compared with the No Action Alternative. Further impacts could occur on the angler experience and associated value based on temperature change impacts on sport fish.

Action Alternative 2

Impacts on economic contributions associated with water-based recreation on Lake Powell and Lake Mead would be as described under Action Alternative 1.

For river-based recreation, impacts on the net economic value from flow changes would be similar to those described under the No Action Alternative.

Cumulative Effects

As discussed above, the SEIS alternatives would result in relatively minor changes in use value and economic activity associated with reservoir and river recreation. The Glen Canyon Dam/Smallmouth Bass flow options would have potential for cumulative impacts on economic contributions associated with sport fisheries within the Glen Canyon Dam to Lake Mead reach of the Colorado River due to changes in water temperature released from Glen Canyon Dam as detailed in **Section 3.14.2**.

Issue 3: How would water shortages impact municipal and industrial uses of water?

Summary

Under all alternatives, allocated water shortages for different elevations in Lake Mead would result in domestic (e.g., municipal and industrial) water shortages compared with 2021 use levels, the last non-shortage year in the Lower Basin. Allocated water shortages are higher under Action Alternatives 1 and 2 than under the No Action Alternative, and the shortages vary by Lake Mead elevation and by state depending on the action alternative. The economic impacts from domestic and industrial water shortages is unknown due to the variety of approaches municipalities and other entitlement holders utilize in shortage scenarios, including supply-side actions (e.g. groundwater recharge, water purchase agreements, and alternative water supplies) and demand-side strategies (e.g. water conservation measures). One study estimated that if all Colorado water was lost for one year, this would result in impacts to 16 million job years and $871 billion in labor income in $2014 for the Upper and Lower Basin Region (James et al. 2014).

Under the No Action Alternative, impacts would be realized at lower shortage scenarios for Arizona entitlement holders (533,000-af scenario) and Nevada entitlement holders (200,000-af scenario) compared with California; this is due to the modeled effects of the 2007 Interim Guidelines and 2019 DCPs. Impacts on California entitlement holders would be realized at the 867,000-af shortage scenario. At a 1.100-maf shortage scenario, maximum levels of shortage would result in domestic water shortages of 178,590 af in Arizona, 30,000 af in Nevada, and 350,000 af in California (based on California's DCP contribution).).

Under Action Alternative 1, impacts would be realized at the lowest shortage level (400,000-af scenario) for Arizona and Nevada entitlement holders, while California would experience impacts starting at the 1.734-maf scenario (based on California's DCP contribution). The lowest levels of shortage (at which the respective state would begin to experience impacts) would result in domestic water shortages of 58,316-af in Arizona, 16,000 af in Nevada, and 200,000 af in California. The maximum levels of shortage in 2024 (2.083-maf shortage scenario) would result in domestic water shortages of 722,586 af in Arizona, 83,230 af in Nevada, and 350,000 af in California (based California's DCP contribution).

Under Action Alternative 2, impacts would be realized at all shortage scenarios in all three states. The lowest levels of shortage would result in domestic water shortages of 1,402-af in Arizona, 15,919 af in Nevada, and 25,827 af in California. The maximum levels of shortage in 2024 (2.083-maf shortage scenario) would result in domestic water shortages of 306,980 af in Arizona, 73,168 af in Nevada, and 400,571 af in California.

No Action Alternative

The driest region of the country—the Census Bureau's Mountain division, comprising Arizona, Colorado, Idaho, Montana, Nevada, New Mexico, Utah, and Wyoming—is expected to grow by approximately 45 percent between 2010 and 2040 (Kearney et al. 2014). Population growth combined with precipitation decreases is leading to increasing demand for municipal water throughout the study area.

As discussed in the 2007 FEIS, shortages to the Arizona M&I sector would be addressed through the state's and each local jurisdiction's drought responses and plans. These responses include supply-side and demand-side actions. Supply-side actions may include groundwater recharge, water purchase agreements, and alternative water supplies, such as brackish water and reclaimed water. Demand-side strategies focus on implementing different stages of water conservation measures as a drought progresses. Some CAP entities would face a priority-specific reduction of project water to zero levels in the absence of alternative water sources, starting at 533,000-af shortage scenario levels. Due to shortages triggered pursuant to the 2007 Interim Guidelines in 2022 and 2023 and contributions that were made under the DCP and other programs in the Lower Division States, some municipalities are already enacting drought response programs that often include a combination of voluntary and enforced restrictions, depending on the anticipated shortage levels (see, for example, Gilbert, Arizona's Supply Reduction Management Plan 2022). **Table 3-128**, below, shows estimated shortages for domestic use.

Table 3-128
No Action Alternative—Impacts on Arizona Domestic Water Shortages from Range of Analyzed Volume of Total Shortages (af)

Arizona	200,000	533,000	617,000	867,000	917,000	967,000	1,017,000	1,100,000
Coconino County	0	0	0	0	0	0	0	0
Gila County	0	0	0	156	156	156	156	390
La Paz County	0	0	0	0	0	0	0	1
Maricopa County	0	78,174	85,482	104,683	104,683	104,683	104,683	133,558
Mohave County	0	0	0	0	0	0	0	3,314
Pima County	0	7,317	7,317	17,986	17,986	17,986	17,986	34,031
Pinal County	0	4,034	4,034	5,337	5,337	5,337	5,337	7,296
Yuma County	0	0	0	0	0	0	0	0
Arizona Domestic Shortages	**0**	**89,525**	**96,833**	**128,162**	**128,162**	**128,162**	**128,162**	**178,590**

In 2024, Arizona M&I shortages would range from approximately 89,525 af during a 533,000-af shortage to 178,590 af during a 1.100-maf shortage. Implementing statewide and local demand-side and supply-side strategies are expected to minimize adverse socioeconomic effects occurring during the maximum M&I shortage under 2024 levels of shortage (see **Table 3-128**).

In California, deliveries to MWD are not anticipated to be adversely affected for Lower Basin shortages until 867,000 af under the No Action Alternative; these reductions are associated with California's contributions under the DCP, which are made notwithstanding the Lower Basin priority system as modeled in the 2007 FEIS. For the purpose of this analysis, these reductions are assumed to result in reduced water availability to MWD, although we acknowledge that flexibility exists for how the DCP contributions may be made. Estimated shortages for domestic use are shown below in

Table 3-129. However, total shortage amounts would be higher than those in Arizona for the higher range of analyzed shortage amounts. The Colorado River supplies approximately 25 percent of MWD water. Drought plans are under development and include storage systems, including groundwater and surface water reservoirs, reverse flow to enhance flexibility of delivery systems, partnership agreements for additional water supply, and in-region programs with member agencies to provide cost-offset opportunities and additional flexibility (MWD 2023).

Table 3-129
No Action Alternative—Impacts on California Domestic Water Shortages from Range of Analyzed Volume of Total Shortages (af)

	200,000	533,000	617,000	867,000	917,000	967,000	1,017,000	1,100,000
California Domestic Shortages[1]	0	0	0	200,000	250,000	300,000	350,000	350,000

[1] Includes the combined area of Los Angeles, Orange, San Diego, Riverside, and San Bernardino Counties supplied by the MWD

In Nevada, shortages to the M&I sector would mostly be borne by the SNWA, which has prepared a water resources plan (SNWA 2023) and adaptive management techniques to address water shortages. Management includes voluntary and involuntary conservation programs as well as water banking. Estimated shortages for domestic use are shown below in **Table 3-130**.

Table 3-130
No Action Alternative—Impacts on Nevada Domestic Water Shortages from Range of Analyzed Volume of Total Shortages (af)

	200,000	533,000	617,000	867,000	917,000	967,000	1,017,000	1,100,000
Nevada Domestic Shortages	8,000	21,000	25,000	27,000	27,000	27,000	27,000	30,000

In the long term, if the current guidelines of the No Action Alternative remained in effect, the water levels would be expected to decline below a critical level in Lake Mead; if water levels decline below this threshold, more severe domestic shortages would be triggered with the potential for additional social and economic impacts.

Action Alternative 1

Under Action Alternative 1, in 2024–2026, Arizona M&I shortages would range from approximately 58,316 af during a 400,000-af shortage to 741,409 af during a 4.000-maf shortage (see **Table 3-131**). Implementing statewide and local demand-side and supply-side strategies would reduce the impacts of 2024 shortage levels on some users; however, for certain priorities at the deepest level of shortage contemplated for 2024, and for shortage levels anticipated in 2025–2026, not all social and economic impacts may be mitigated. Should shortages result in a reduction or elimination of legal access to municipal water, widespread impacts on social and economic conditions may be possible. In some scenarios, municipalities may find the need to utilize alternative water sources, or trucked water, as an alternative to support continued services. The exact costs of these actions are unknown and would depend on numerous factors, including but not limited to, market conditions for alternative water sources and distance from alternative sources (such as for trucked water costs).

In addition to direct costs associated with water replacement, other indirect social costs may occur as a result of a reduction in ecosystem services, or benefits to people provided by the environment. For example, trees in urban areas have been shown to provide high levels of benefits to people in the form of shade (mitigating impacts of increasing temperatures from climate change), local air quality improvements, and enhancement of the visual setting. Should a reduction in domestic water supply result in die-offs of urban and suburban area trees, this could represent a loss of value that would take decades to recapture, due to the growth time required for trees (see, for example, Broome et al. 2016).

Under Action Alternative 1, in California, deliveries to MWD are not modeled as being adversely affected by Lower Basin shortages until 2.083 maf as a result of modeling assumptions about the priority system in the Lower Basin. However, California is assumed to continue making contributions required under the DCP, which begin sooner and are independent of the priority system. See **Appendix D**, Shortage Allocation Model, for additional details. **Table 3-132**, below, shows the estimated shortages for domestic use.

In Nevada, the maximum shortage would equal 160,000 af, more than half the state's apportionment. With Nevada's drought plan in place, shortages to the M&I sector may be managed. Socioeconomic effects on southern Nevada's M&I sector would vary depending on the size of the shortage and the ability of adaptive management policies to mitigate impacts.

Action Alternative 2

Under Action Alternative 2, in 2024–2026, Arizona M&I shortages would range from 238,007 af during a 400,000-af shortage to 1,387,109 af during a 4.000-maf shortage (see **Table 3-134**, below). Impacts, as described under Action Alternative 1, could occur; however, the impacts would occur at a reduced intensity due to the distribution of shortages in the same percentage across all Lower Basin water users rather than based on priority level.

In California, under Action Alternative 2, deliveries for domestic use would impact a wider range of users than under the other alternatives during the 2024–2026 analysis period. This is due to the distribution of shortages in the same percentage across all Lower Basin water users under this alternative. Impacts would occur at all shortage levels, with up to 724,491 af of shortage overall under the 4.000-maf shortage scenario. Estimated shortages for domestic use are shown below in **Table 3-135**.

In Nevada, estimated shortages would result in impacts as discussed under Action Alternative 1; however, impacts would occur at a slightly reduced level due to the distribution of shortages in the same percentage across all Lower Basin water users. See **Table 3-136**.

Table 3-131
Action Alternative 1 Impacts on Arizona Domestic Water Shortages from Range of Analyzed Volume of Total Shortages

Arizona	**400,000**	**1,066,000**	**1,234,000**	**1,734,000**	**2,083,000**	**2,250,000**	**2,500,000**	**3,000,000**	**3,333,000**	**3,667,000**	**4,000,000**
Coconino County	0	0	0	9	9	9	9	9	9	9	9
Gila County	0	1,280	1,740	2,906	2,906	2,906	2,906	2,906	2,906	2,906	2,906
La Paz County	0	11	67	1,217	1,239	1,239	1,793	3,904	5,310	6,721	8,127
Maricopa County	46,965	243,406	300,231	447,506	449,732	450,724	452,210	455,181	457,160	459,145	461,124
Mohave County	0	8,208	10,865	19,138	19,277	19,290	19,309	19,348	19,373	19,399	19,425
Pima County	7,317	94,976	126,499	206,357	206,357	206,357	206,357	206,357	206,357	206,357	206,357
Pinal County	4,034	14,739	18,589	28,341	28,341	28,341	28,341	28,341	28,341	28,341	28,341
Yuma County	0	4	8	14,991	14,995	14,995	14,995	14,995	14,995	15,019	15,120
Arizona Domestic Shortages	**58,316**	**362,624**	**457,998**	**720,464**	**722,856**	**723,861**	**725,920**	**731,041**	**734,452**	**737,896**	**741,409**

Table 3-132
Action Alternative 1—Impacts on California Domestic Water Shortages from Range of Analyzed Volume of Total Shortages (af)

	400,000	1,066,000	1,234,000	1,734,000	2,083,000	2,250,000	2,500,000	3,000,000	3,333,000	3,667,000	4,000,000
California Domestic Shortages	0	0	0	0	261,593	389,176	502,287	665,231	773,752	834,052	843,052

[1] Includes the combined area of Los Angeles, Orange, San Diego, Riverside, and San Bernardino Counties supplied by the MWD

Table 3-133
Action Alternative 1—Impacts on Nevada Domestic Water Shortages from Range of Analyzed Volume of Total Shortages (af)

	400,000	1,066,000	1,234,000	1,734,000	2,083,000	2,250,000	2,500,000	3,000,000	3,333,000	3,667,000	4,000,000
Nevada Domestic Shortages	16,000	42,640	49,360	69,360	83,320	90,000	100,000	120,000	133,320	146,680	160,000

Table 3-134
Action Alternative 2—Impacts on Arizona Domestic Water Shortages from Range of Analyzed Volume of Total Shortages (af)

Arizona	**400,000**	**1,066,000**	**1,234,000**	**1,734,000**	**2,083,000[1]**	**2,250,000**	**2,500,000**	**3,000,000**	**3,333,000**	**3,667,000**	**4,000,000**
Coconino County	0	1	1	1	1	2	2	2	3	3	3
Gila County	0	156	482	789	942–1,126	1,065	1,218	1,740	1,986	2,200	2,415
La Paz County	385	1,025	1,187	1,668	1,891–2,243	2,468	2,853	3,655	4,296	4,939	5,579
Maricopa County	0	104,683	144,911	182,794	201,735–224,465	216,888	235,830	300,231	330,537	357,055	383,573
Mohave County	603	1,606	1,859	2,613	2,962–3,514	3,866	4,469	5,726	6,729	7,736	8,739
Pima County	0	17,986	40,336	61,351	71,859-84,468	80,265	90,772	126,499	143,311	158,022	172,732
Pinal County	0	5,337	8,066	10,633	11,196-13,456	12,942	14,226	18,589	20,642	22,438	24,235
Yuma County	414	1,104	1,278	1,796	2,036–2,415	2,658	3,072	3,936	4,626	5,318	6,008
Arizona Domestic Shortages	**1,402**	**131,899**	**198,120**	**261,644**	**293,925–306,980**	**320,155**	**352,442**	**460,377**	**512,710**	**557,710**	**603,284**

[1] Includes a range of shortages based on Lake Mead's elevation

Table 3-135
Action Alternative 2—Impacts on California Domestic Water Shortages from Range of Analyzed Volume of Total Shortages (af)

	400,000	1,066,000	1,234,000	1,734,000	2,083,000[1]	2,250,000	2,500,000	3,000,000	3,333,000	3,667,000	4,000,000
MWD Service Area[2]	25,787	68,722	79,552	311,786	400,337–487,443	465,422	541,209	594,974	637,909	680,973	723,908
San Bernardino County	36	97	112	158	179–212	2,338	269	345	406	466	527
Riverside County	1	3	4	6	6–7	8	9	12	14	16	18
Imperial County	3	7	8	11	13–15	17	19	24	29	33	37
California Domestic Shortages	**25,827**	**68,829**	**79,676**	**311,960**	**400,571–487,658**	**465,680**	**541,507**	**595,356**	**638,358**	**681,489**	**724,491**

[1] Includes a range of shortages based on Lake Mead's elevation

[2] Includes the combined area of Los Angeles, Orange, San Diego, Riverside, and San Bernardino Counties supplied by the MWD

Table 3-136
Action Alternative 2—Impacts on Nevada Domestic Water Shortages from Range of Analyzed Volume of Total Shortages (af)

	400,000	1,066,000	1,234,000	1,734,000	2,083,000	2,250,000	2,500,000	3,000,000	3,333,000	3,667,000	4,000,000
Nevada Domestic Shortages1	15,919	42,104	49,430	61,329	68,922–73,168	77,800	85,719	105,230	118,415	131,640	144,825

[1] Includes a range of shortages based on Lake Mead's elevation

Cumulative Effects

The potential operational changes included in the Glen Canyon Dam/Smallmouth Bass flow options would not impact water shortage amounts for municipal and industrial uses or associated economic contributions.

3.17 Environmental Justice

3.17.1 Affected Environment

Executive Order 12898, "Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations" (59 *Federal Register* 7629, February 11, 1994; US President 1994b), formally requires federal agencies to incorporate environmental justice as part of their missions. Specifically, it directs them to address, as appropriate, any disproportionately high and adverse human health or environmental effects of their actions, programs, or policies on minority and low-income populations.

Analysis consists of two steps: 1) screening of populations within the study area to identify the presence of communities for further environmental justice consideration, and 2) review of impacts on determine potential for disproportionate adverse impacts on these communities.

As in the 2007 FEIS, the environmental justice study area is defined by those counties that may be impacted by management direction, resulting in water shortages or changes to water-based recreation.

While the California, Nevada, and Utah study areas are the same as those described in the 2007 FEIS and detailed in the Socioeconomic section, the Arizona study area for this SEIS has been expanded to include four additional counties: Apache, Gila, Graham, and Navajo. The Arizona study area from the 2007 FEIS consisted of Coconino, La Paz, Maricopa, Mohave, Pima, Pinal, Yuma, and Yavapai Counties. The Arizona study area for this SEIS includes 12 counties. Information is provided below on locations within these counties that receive water deliveries and the rationale for the expansion of the study area.

As of 2023, water rights settlements involving Colorado River water delivered through the CAP water have been executed with the Ak-Chin Indian Community, Fort McDowell Yavapai Nation, Gila River Indian Community (GRIC), San Carlos Apache Tribe, Salt River Pima-Maricopa Indian Community, Tohono O'odham Nation, Yavapai-Prescott Indian Tribe, Hualapai Tribe, and White Mountain Apache Tribe. CAP water is also set aside for the Navajo Nation. Additional details are included in **Section 3.18**, Indian Trust Assets (ITAs).

Map 3-2 provides an overview of the environmental justice study area and population centers within it. **Map 3-2** also displays the environmental justice study area counties in relation to the two major storage reservoirs (Lake Powell and Lake Mead) with major water surface level fluctuations. While not shown in this map, several other mainstream dams are present. While this analysis presents data and identifies environmental justice communities at the county level, it should be noted that additional environmental justice communities may be present at a smaller geographic scale.

BUREAU OF RECLAMATION

Map 3-2
Environmental Justice Study Area

- Environmental justice study area: counties that may be affected by management direction, resulting in water shortages or changes to water-based recreation
- Populated place
- Dam
- Colorado River
- Colorado River tributary
- Colorado River Basin, Upper and Lower Basins
- States in the Colorado River Basin

This page intentionally left blank.

Each county was screened to identify the presence of low-income, minority, and Native American populations that would meet the criteria for identification as populations for further consideration for environmental justice concerns.

This section identifies environmental justice communities in the analysis area based on the following criteria:

- CEQ 1997 guidance states that minority or low-income populations should be identified where either (1) the minority or low-income population of the affected area exceeds 50 percent, or (2) the minority or low-income population percentage of the affected area is meaningfully greater than the minority population percentage in the general population or other appropriate unit of geographic analysis. The total minority populations are defined as the total population minus those who identify as White, of non-Hispanic descent. For the meaningfully greater analysis, Reclamation used 110 percent of the minority percentage of the geographic reference area as the threshold for meaningfully greater. For Arizona, California, Nevada, and Utah, 110 percent of the total minority population is 35.1 percent, 43.5 percent, 32.2 percent, and 15.8 percent, respectively.
- Low-income populations are defined relative to the annual statistical poverty thresholds from the US Census Bureau (CEQ 1997). The guidance does not provide criteria for determining low-income populations as specifically as it does for minority populations. Therefore, for this analysis, low-income populations are defined as people whose income is less than or equal to twice (200 percent of) the federal "poverty level." For this analysis, populations are considered low-income populations when 1) 50 percent of the population is classified as low income, or 2) any geographic area of analysis has a low-income percentage of the population equal to or higher than the reference area.
- Federally recognized Tribes are considered environmental justice populations in and of themselves; when possible, they are included in the analysis as separate minority populations. For this analysis, additional screening was utilized to review US Census Bureau data for those who identify as American Indian or Alaska native alone or in combination with one or more other races. Reclamation also used a threshold analysis and meaningfully greater analysis to identify Indigenous populations that meet the criteria for environmental justice consideration. The 50 percent threshold analysis involves identifying any block groups with a total Indigenous population 50 percent or greater.

Table 3-137 provides an overview of the environmental justice screening results for the study area.

Overall, 19 of the 22 study area counties met at least one environmental justice criterion (11 Arizona counties, 1 Nevada county, 3 Utah counties, and 4 California counties). As such, there are a total of 19 environmental justice populations in the study area. In Arizona, Apache, Gila, Graham, Navajo, and Pima Counties had minority, low-income, and Indigenous populations that met the criteria. San Bernadino County, California, also had minority, low-income, and Indigenous populations that met the criteria. See **Table 3-137** for more information; details for each indicator are provided below.

Table 3-137
Study Area Environmental Justice Screening Results (2021)

Geographic Area	Minority Population Percentage of Geographic Area (Meaningfully Greater Percentage)	Indigenous Population Percentage of Geographic Area	Low-income Population Percentage of Geographic Area	Meets Criteria for Environmental Justice Communities of Concern?
Reference Area				
Arizona	31.9 (35.1)	5.8	31.7	-
California	39.5 (43.5)	2.3	28.5	-
Nevada	29.3 (32.2)	2.5	31.2	-
Utah	14.4 (15.8)	2.0	24.7	-
Apache County, Arizona	82.3*	75.0*	59.3*	Yes
Coconino County, Arizona	14.6	28.7*	37.4*	Yes
Gila County, Arizona	38.9*	19.6*	40.9*	Yes
Graham County, Arizona	49.6*	14.6*	42.3*	Yes
La Paz County, Arizona	28.3	18.4*	44.3*	Yes
Maricopa County, Arizona	31.5	3.2	28.6	No
Mohave County, Arizona	24.1	3.6	38.3*	Yes
Navajo County, Arizona	58.7*	46.3*	49.9*	Yes
Pima County, Arizona	38.0*	6.1*	34.4*	Yes
Pinal County, Arizona	30.9	6.5*	31.3	Yes
Yavapai County, Arizona	20.6	3.2	32.0*	Yes
Yuma County, Arizona	64.7*	2.8	44.0*	Yes
Imperial County, California	85.1*	2.3	46.6*	Yes
Los Angeles County, California	48.7*	2.1	32.2*	Yes
Orange County, California	34.0	1.5	23.3	No
Riverside County, California	50.3*	2.2	30.4*	Yes
San Bernardino County, California	54.6*	2.6*	34.4*	Yes
San Diego County, California	34.3	2.0	25.2	No
Clark County, Nevada	31.8*	2.0	32.5*	Yes
Garfield County, Utah	6.2	4.6*	40.2*	Yes
Kane County, Utah	3.2	5.1*	31.5*	Yes
San Juan County, Utah	6.0	49.8*	44.1*	Yes

US Census Bureau 2021a, 2021b, 2021c

Further, 11 of the 12 Arizona study area counties, which each contain communities that receive CAP water deliveries or rely on Colorado River mainstream water, are identified as environmental justice communities, based on the criteria described above. The only exception is Maricopa County, which did not have minority, low-income, or Indigenous populations that exceeded the respective thresholds. While Maricopa County did not have an Indigenous or minority population that met the criteria, it is important to note that both the Salt River Pima-Maricopa Indian Community and the Fort McDowell Yavapai Nation are located within Maricopa County.

Minority Population

In Arizona, 6 of the 11 counties had total minority populations that exceeded the meaningfully greater threshold of 35.1 percent. In addition, Apache, Navajo, and Yuma Counties had total minority populations well above 50 percent, ranging from 58.7 percent to 82.3 percent. The total minority population in Clark County, Nevada, exceeded the meaningfully greater threshold of 32.2 percent and is considered an environmental justice community. In California, all counties, excluding Orange and San Diego Counties, had minority populations that met the meaningfully greater threshold of 43.5 percent. No counties in Utah had minority populations that exceeded the meaningfully greater threshold of 15.8 percent. As such, there were no identified environmental justice communities. **Map 3-3** displays the minority populations at the county level.

Indigenous Population

In Arizona, all counties, excluding Maricopa, Mohave, and Yavapai Counties, had Indigenous populations exceeding the state average Indigenous population (5.8 percent) and are considered environmental justice communities. In California, only San Bernadino County had an Indigenous population exceeding the state average (2.3 percent). No counties in Nevada had an Indigenous population that exceeded the state average (2.5 percent). In Utah, all three counties had Indigenous populations that exceeded the state average (2.0 percent), and the Indigenous population in San Juan County, Utah, was notably higher than the other study area counties. **Map 3-4** displays the Indigenous populations at the county level.

Low-Income Population

For Arizona, all study area counties, excluding Maricopa County (28.6 percent) and Pinal County (31.3 percent), had low-income populations exceeding the state average (31.7 percent). For California, all study area counties, excluding Orange County (23.3 percent) and San Diego County (25.3 percent), had low-income populations that exceeded the state average (28.5 percent). All three study area counties in Utah and the single study area county in Nevada had low-income populations that exceeded the state averages (24.7 percent and 31.2 percent, respectively). **Map 3-5** displays low-income populations at the county level.

3.17.2 Environmental Consequences

Methodology

This section relies on analysis in other resource sections to identify whether any of the alternatives are likely to have adverse human health or environmental impacts. These impacts are discussed in the context of potential for disproportionate adverse impacts on identified environmental justice communities.

Impact Analysis Area

The impacts analysis area is the same as that described in **Section 3.17.1**. This analysis provides baseline information for the environmental justice study area counties; however, there are communities who could experience more impacts from water shortages and changes to water deliveries. For instance, there are areas within the Arizona environmental justice study area counties in which there are no replacement water sources. Should these areas experience water shortages that result in available water being reduced to zero, impacts would be more severe compared with areas where replacement water sources exist.

Assumptions

The Shortage Allocation Model does not account for replacement water sources. Refer to **Appendix D** for more information on the Shortage Allocation Model assumptions.

Impact Indicators

- Disproportionate and adverse human health or environmental impacts
- Shortage levels at which available water would be reduced to zero for priorities/users located within environmental justice study area counties

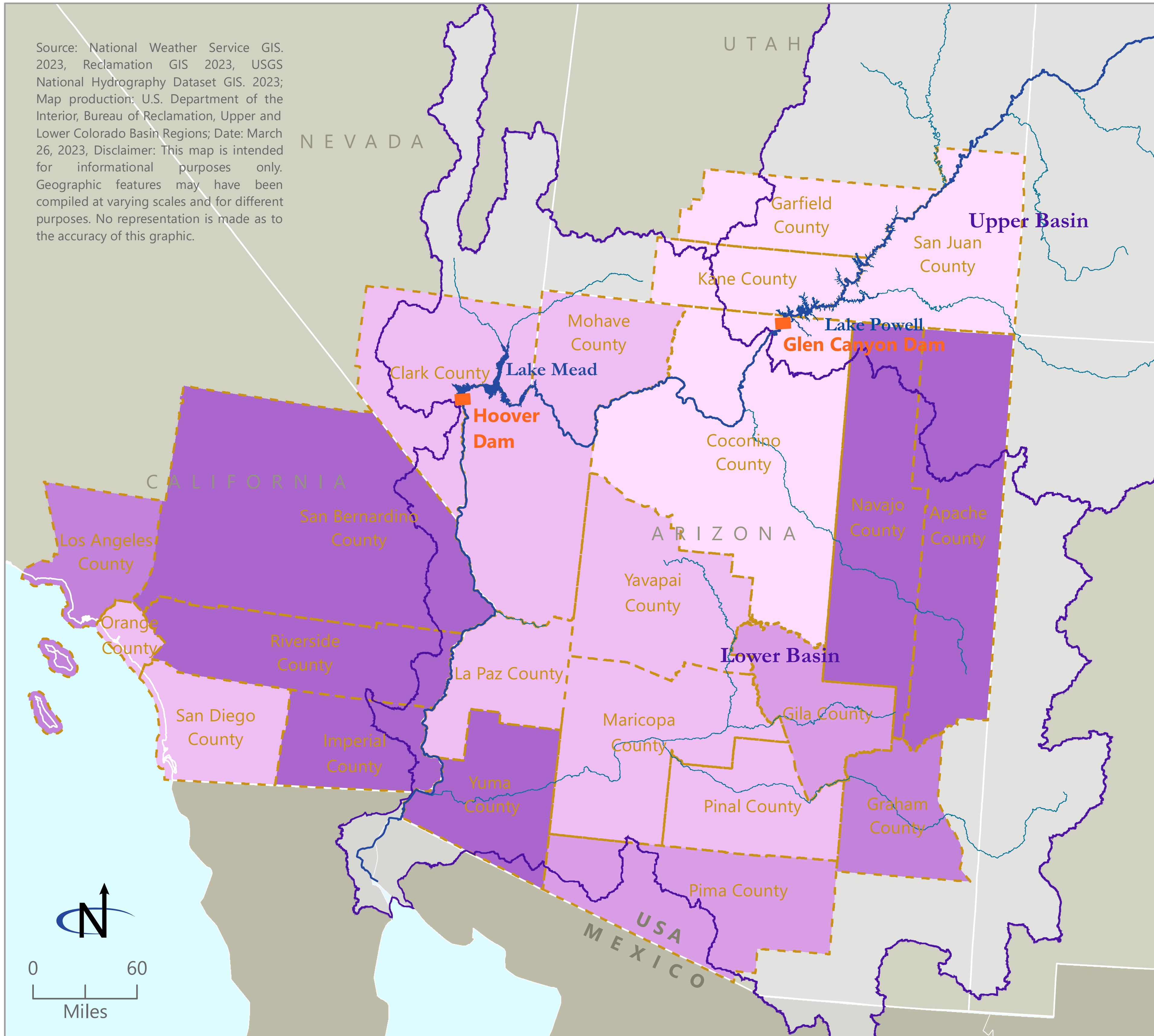
Issue 1: How would management decisions affect environmental justice communities?

Summary

Under the No Action Alternative, there were no modeled shortage levels that resulted in available water being reduced to zero under any priorities for California and Nevada. However, if shortages reached 533,000 to 617,000 af, available water would be reduced to zero for fourth priorities in Arizona. Arizona fifth and sixth priorities are not available in any level of shortage. Some users in Maricopa, Pinal, and Pima Counties would have their water supply reduced to zero and would need to locate alternative water sources to continue historical levels of consumptive use.

It should be noted that shortage levels modeled in the No Action Alternative would be less than those for the action alternatives in the short term. However, projections based on low-flow hydrology scenarios indicate that, without a change to current operational guidelines, decreasing reservoir levels would result in increased system shortages, potentially limiting the ability to deliver water. This could result in an increased level of impacts on environmental justice communities.

Under Action Alternative 1, additional modeled shortage levels in the near term (2024–2026) indicate that available water would be reduced for additional counties in Arizona (La Paz, Mohave, and Yuma Counties), compared with the No Action Alternative. As such, impacts on irrigation and domestic use from water shortages would be more widely distributed under Action Alternative 1 compared with the No Action Alternative for this time period. While the shortage levels at which available water would be reduced to zero would vary by state and priority, a higher total number of environmental justice study area counties would experience available water reaching zero under Action Alternative 1 for this time period. In the longer term, hydrology models indicate that reservoir levels would be maintained above critical levels for a longer length of time with the implementation of these shortages. Therefore, impacts on environmental justice communities could be reduced compared with the No Action Alternative in the long term.



BUREAU OF RECLAMATION

Map 3-3
Minority Populations for Environmental Justice Consideration

Percent of the population identifying as a racial and/or ethnic minority at the county level

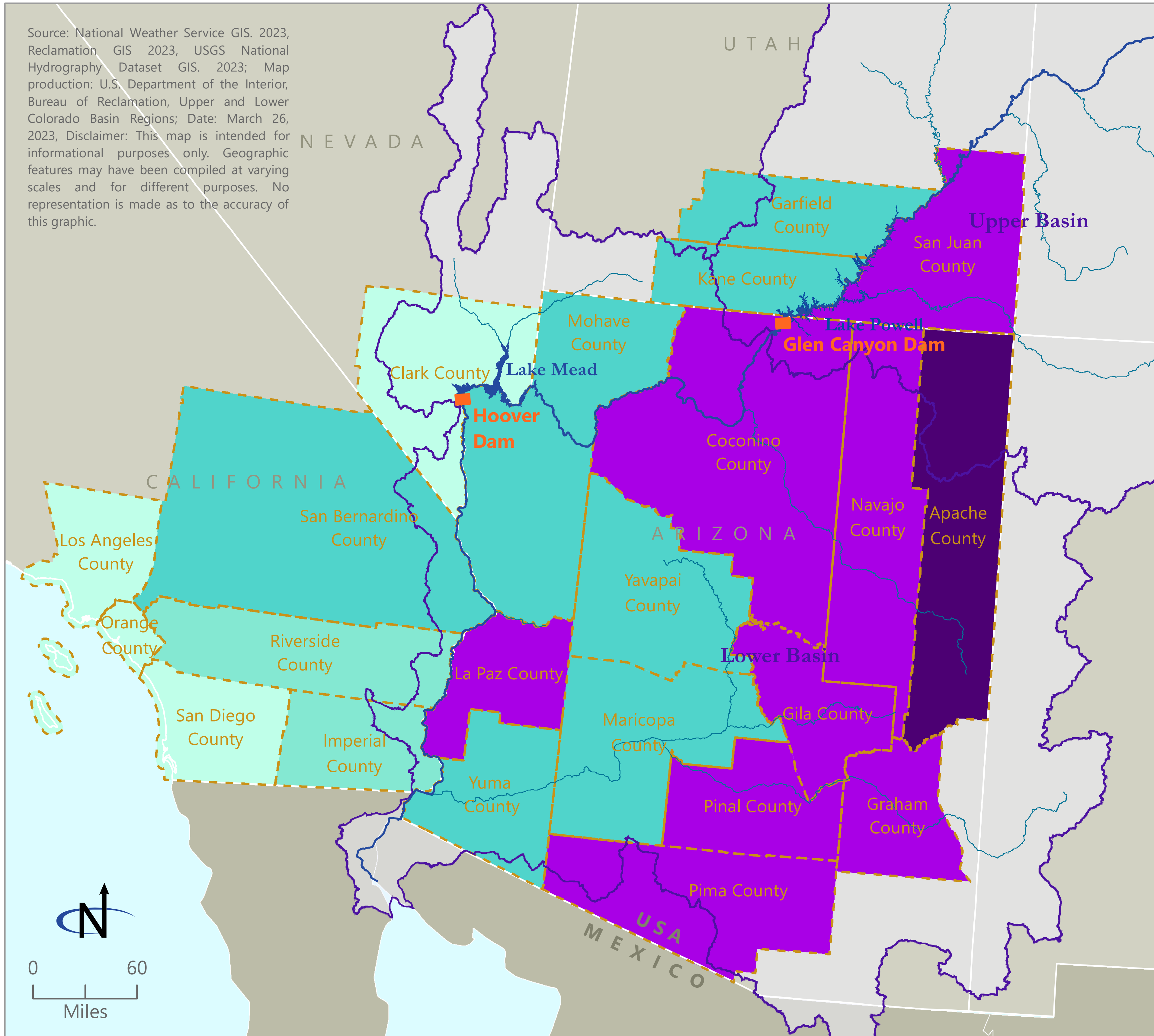
- 0-15.0
- 15.1-35.0
- 35.1-45.0
- 45.1-50.0
- 50.1-85.1

State	% minority population meaningfully greater threshold
Arizona	35.1
California	43.5
Nevada	32.2
Utah	15.8

- Environmental justice study area: counties that may be affected by management direction, resulting in water shortages or changes to water-based recreation
- Dam
- Colorado River
- Colorado River tributary
- Colorado River Basin, Upper and Lower Basins
- States in the Colorado River Basin

BUREAU OF RECLAMATION

Map 3-4
Indigenous Populations for Environmental Justice Consideration



Percent of the population identifying as a American Indian or Alaska Native (alone or in combination with one or more other races) at the county level

- 1.5- 2.2
- 2.3- 2.5
- 2.5- 5.7
- 5.8-50.0
- 50.1-75.0

State	% Indigenous population state threshold
Arizona	5.8
California	2.3
Nevada	2.5
Utah	2.0

Environmental justice study area: counties that may be affected by management direction, resulting in water shortages or changes to water-based recreation

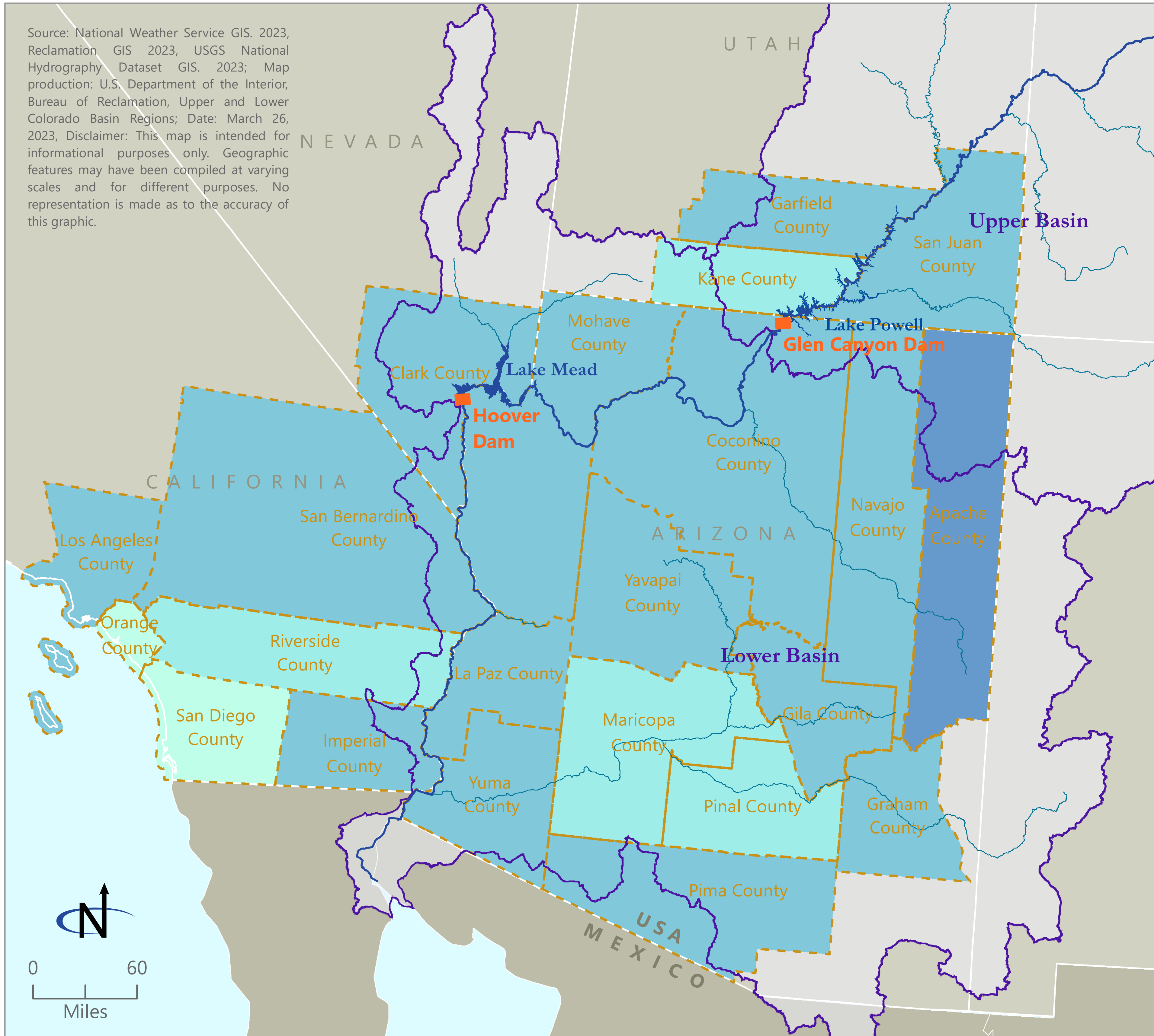
Dam

Colorado River

Colorado River tributary

Colorado River Basin, Upper and Lower Basins

States in the Colorado River Basin



— BUREAU OF —
RECLAMATION

Map 3-5
Low-income Populations for Environmental Justice Consideration

Percent of the population identifying as living at or below 200 percent of the federal poverty level

- 23.0-28.4
- 28.5-31.5
- 31.6-50.0
- 50.1-59.3

State	% low-income population state threshold
Arizona	31.7
California	28.5
Nevada	31.2
Utah	24.7

Environmental justice study area: counties that may be affected by management direction, resulting in water shortages or changes to water-based recreation

Dam

Colorado River

Colorado River tributary

Colorado River Basin, Upper and Lower Basins

States in the Colorado River Basin

This page intentionally left blank.

Compared with the No Action Alternative and Action Alternative 1, Action Alternative 2 would result in less concentration of impacts on individual users, including those located within environmental justice counties. As such, the impacts would be more widely distributed. Under Action Alternative 2, an increased number of users would experience water shortages, whereas under the No Action Alternative, the same users may not experience shortages. While some users, including those within environmental justice communities, would still experience water shortages, the distribution of shortage would be such that impacts would be less concentrated and lower in magnitude for some communities.

No Action Alternative

Under the No Action Alternative, a range of volumes of total shortage to Lower Division States were analyzed using a Shortage Allocation Model. Potential water shortages would not impact water deliveries in California or Nevada to the degree that there would be zero water for any priorities under the No Action Alternative, as detailed in **Section 3.7**, Water Deliveries.

Eleven of the Arizona counties are environmental justice communities. Two of the three counties served by the CAP are environmental justice communities (Pinal and Pima). A Lower Basin shortage would cause the reduction of water deliveries first to the CAP and other post-1968 Colorado River contractors in Arizona.

Under the No Action Alternative, there are shortage levels where available water for users under some priorities would be reduced to zero in Arizona. According to the model results, at water shortage levels ranging from 533,000 af to 1.100 maf, some water users within the Arizona environmental justice study area counties would be reduced to zero water availability under certain priorities of Colorado River water. These impacts are discussed in further detail below. The degree to which these shortages would result in disproportionate adverse impacts would depend on the availability and cost of alternative water supplies.

Irrigation

At shortage levels of 533,000 af and greater, available water for users under 5th (unused entitlement/apportionment) and 6th (surplus) priority entitlements along the mainstream Colorado River, and users of the CAP excess pool in Maricopa, Pinal, and Pima Counties, Arizona, would be reduced to zero.

Domestic Use

At levels of shortage of 533,000 af and greater, domestic water supply from the CAP NIA-B[27] priority in Maricopa, Pinal, and Pima Counties would not be available. If water shortages reached 617,000 af, available water for users under the CAP NIA-A priority would also be reduced to zero.

Tribal Allocations

Under the No Action Alternative, available water for all users under CAP NIA-A priority in Maricopa, Pima, and Pinal Counties would be reduced to zero if water shortages reached 617,000 af. At this shortage level, available water would be reduced to zero for some Tribal allocations (Tohono

[27] NIA refers to Non-Indian agricultural. NIA-A refers to NIA priority contracts and subcontracts executed prior to 2021. NIA-B refers to NIA priority contracts and subcontracts executed in 2021 or later.

O'odham Nation and Gila Indian River Community). However, even when water deliveries are reduced to Tribes, the underlying water rights would not be affected.

Action Alternative 1

The Shortage Allocation Model utilizes different volume inputs of state shortage for the No Action Alternative and Action Alternative 1. As such, under Action Alternative 1, the shortage level at which available water for some users under some priorities in Arizona would be reduced to zero would be lower (400,000 af) compared with under the No Action Alternative (533,000 af). However, the Shortage Allocation Model for Action Alternative 1 and the No Action Alternative would produce an identical distribution between Arizona users if the volumes of shortage to Arizona were the same.

Under Action Alternative 1, water shortages ranging from 400,000 af to 4.000 maf would result in some water users within the Arizona environmental justice study area counties who receive water deliveries from the CAP and/or the Colorado River mainstream to be reduced to zero. Detailed information is provided below.

Action Alternative 1 would result in more impacts on water deliveries to users in the states of Arizona, California, and Nevada, compared with the No Action Alternative.

Hydrologic Resources and Water Deliveries

Irrigation

If shortages reached 1.734 maf, water supply for one (priority 3) entitlement holder in Yuma County would be reduced to zero. If shortages reached 2.083 maf, water supply from the Colorado River mainstream for irrigation use would be reduced to zero for some users (all 4(i) priority entitlement holders and one 3 priority entitlement holder) in La Paz, Yuma, and Mohave Counties. This would result in impacts on irrigation.

La Paz, Mohave, and Yuma Counties are identified as environmental justice communities. As such, the water users within these counties who would have water delivery reduced to zero would face disproportionate consumptive-use impacts on irrigation. Farmers who have historically relied on water allocations from the CAP and Colorado River to irrigate crops would need to use alternative water supplies, such as groundwater, if available, to continue agricultural production.

Through the 2024 operating year, available water supply for irrigation use would not be reduced to zero for any priorities in California or Nevada (see **Appendix D**).

Domestic Use

Consumptive-use impacts on domestic uses would vary by volume of total shortage to the Lower Division States. The number of counties, different types of priority holders, and different types of entitlement holders who would face zero water supply increases as the volume of total shortage to Lower Division States increased (see **Appendix D**, Shortage Allocation Model).

If water shortages reached 400,000 af, water supply from the CAP for domestic use would be reduced to zero for some users in Maricopa, Pinal, and Pima Counties (all users with CAP NIA-B priority). The shortage level at which available water for users under CAP NIA-B priority is reduced to zero is smaller than that of the No Action Alternative. However, this is a result of the Shortage Allocation Model using different state shortage volumes for the No Action Alternative and Action Alternatives 1 and 2. As Lake Mead's elevation decreases, 2024 additional shortage increases for the Lower Division States as a whole and individually. The same is true for the 2025–2026 total shortage.

If water shortages reached 1.066 maf, water supply from the CAP for domestic use would be reduced to zero for some users in Maricopa, Pinal, and Pima Counties (all users with CAP NIA-B and CAP NIA-A priority). Water supply for these users would be reduced to zero for all subsequent shortage volume scenarios as well.

If water shortages reached 1.734 maf or 2.083 maf, water supply from the CAP and from the Colorado River mainstream would be reduced to zero for some users within Coconino, Gila, La Paz, Maricopa, Mohave, Pima, Pinal, and Yuma Counties. Through the 2024 operating year, the available water supply for domestic use would not be reduced to zero for any priorities in California or Nevada (see **Appendix D**). Coconino, Gila, La Paz, Mohave, Pima, Pinal, and Yuma Counties, Arizona, are identified as environmental justice communities. As such, the water users within these counties who would experience zero water supply would face disproportionate consumptive-use impacts on domestic uses.

Tribal Allocations

Under Action Alternative 2, the available water supply would not be reduced to zero for any Tribes in California or Nevada (see **Appendix D**).

The allocations discussed in this section are based on the Shortage Allocation Model, which is more detailed and specific than the regional analysis presented in **Section 3.7.2**, *Issue 6* (see also **Appendix D**). If water shortages reached 1.066 maf, NIA-A priority water supply from the CAP would be reduced to zero for two Tribal communities in Maricopa, Pima, and Pinal Counties (the same communities impacted under the No Action Alternative). The same is true for these communities under the 1.234-maf, 1.734-maf, and 2.083-maf total shortage scenarios. If water shortages reached 1.734 maf, fourth-priority water supply from the CAP are modeled to be reduced to zero for most contractors and subcontractors, including seven Tribes (in Gila, Maricopa, Pima, and Pinal Counties). If water shortages reached 2.083 maf, water supply from the Colorado River mainstream is modeled to be reduced to zero for a Tribe's agricultural lands in La Paz County that is served pursuant to the Tribe's priority-four water delivery contract.

Gila, La Paz, Pima, Pinal, and Yuma Counties are identified as environmental justice communities. As such, the water users within these counties could face temporary, disproportionate consumptive-use impacts on Tribal allocations for irrigation and domestic use. Production on Tribal lands provides an important economic base for many Tribal communities, including those in the Arizona study area (Deol and Colby 2018). A lack of water supply could result in reduced agricultural production and a loss of Tribal revenue. The Ak-Chin Indian Community, Tohono O'odham Nation, and GRIC engage in on-reservation farming. The aforementioned shortages could impact on-reservation farming and could result in disproportionate impacts from losses in revenue.

However, it is important to note that losses in revenue are impacted by other factors, including, but not limited to, the implementation of water rights settlements and availability of other resources.

Studies have documented impacts associated with losses in revenue. For example, one Utah State University study, which included several Tribes in Arizona, including the Tohono O'odham Nation, found that reductions in cattle and hay production due to drought result in reduced economic activity in related sectors and significant economic losses for Tribal economies in Arizona (Drugova et al. 2020). As detailed in **Section 3.16.2**, shortage allocations based on priority may result in the loss of production for Tribal agricultural lands for a given year. Water delivery reductions may result in fallowing of some Indian lands, with the potential for economic impacts, as described above. However, annual variability in water deliveries and associated use and economic contributions would not affect the underlying settled water rights.

Water Quality

Potential changes to water quality were evaluated for salinity, temperature, metals, and perchlorate. Effects on these parameters would be minor and would not disproportionately affect any environmental justice communities in the study area. As elevations decrease, the dilution capacity of Lake Powell and Lake Mead would also decrease but would not likely result in any significant decrease in dilution capacity or increase in concentrations of metals of concern, including for environmental justice communities. However, quantified water-quality impacts related to dilution capacity are not available; therefore, it is difficult to project the quantified water-quality impacts, and alternatives cannot be compared (**Section 3.8**). Under any alternative, salinity would not exceed numeric salinity criteria established by the Colorado River Basin Salinity Control Forum.

Air Quality and Climate Change

Potential changes to fugitive dust emissions due to exposed shoreline are minor at Lake Powell and there would be no disproportionate effect on the health of residents of San Juan County compared with the other counties. Likewise, there would be no significant difference among alternatives at Lake Mead or downstream. Under Action Alternative 1, there would be no increase in GHG emissions due to alternative power sources (see **Section 3.9**, Air Quality). Therefore, Action Alternative 1 would not result in any disproportionate effects on environmental justice communities.

Visual Resources

Potential impacts on visual resources were considered for attraction features, calcium carbonate rings, and sediment deltas (for both Lake Mead and Lake Powell), which would be viewed from adjacent highways, from the lake surface, and from trails in the area. While some of these features (for example, Rainbow Bridge) are located within San Juan County, Utah, an environmental justice community, effects are not disproportionate or unique to any environmental justice community.

Additionally, potential impacts on landscape character along the Colorado River between Glen Canyon Dam and Lake Mead (associated with potentially lower flows through Grand Canyon) and impacts on landscape character associated with decreasing water deliveries/allocations in the Lower Division States were considered (see **Section 3.10**, Visual Resources). Changes to the natural landscape character along the Colorado River between Glen Canyon Dam and Lake Mead (associated with potentially lower flows through Grand Canyon) would impact any environmental justice communities located within these areas. Additionally, impacts on the irrigated, agricultural landscapes within the Lower Division States, where the influence of the Colorado River into adjacent lands could narrow as these areas would begin transition to their natural, arid condition, resulting in large-scale changes to landscape character compared with the existing condition. These changes to visual resources would also impact environmental justice communities within or adjacent to these landscapes.

Biological Resources

Potential impacts on biological resources would not disproportionately impact any environmental justice community identified within the study area. Potential impacts on vegetation, wildlife, and fish due to the action alternatives would be similar.

Scoping and subsequent consultation did not result in the identification of any environmental justice community for whom indigenous fish, vegetation, or wildlife constituted a significant portion of their diet. There will be no difference in rates or patterns of subsistence consumption by environmental justice communities, including Indian Tribes, in comparison to the general population in the study area. See **Section 3.13**, Biological Resources, for more detailed information.

Cultural Resources

Section 3.11.2 analyzes how changes in operations would affect TCPs and resources of concern to Native Americans. Action Alternative 1 would have fewer impacts on sacred sites and TCPs than the No Action Alternative. Under this alternative, visitor access to previously inundated sacred sites could increase to a lesser degree than under the No Action Alternative. Adverse effects on sacred sites and TCPs could disproportionately impact Tribes for whom these resources provide cultural or spiritual significance and value. However, adverse effects on TCPs would be resolved through the LTEMP PA, land management agency actions, or the NHPA Section 106 process. See **Section 3.11**, Cultural Resources, for detailed information.

Indian Trust Assets

Reclamation has concluded that Action Alternative 1 would have no significant impacts on ITAs. Reclamation is committed to protecting and maintaining ITAs and rights reserved by or granted to Indian Tribes or individual Indians by treaties, statutes, and executive orders. See **Section 3.18**, Indian Trust Assets, for more detailed information.

Electrical Power Resources

Changes to electrical power production among the alternatives have the potential to affect environmental justice communities disproportionately through possible increases in electricity rates resulting from decreased electrical power generation under both action alternatives. However, the facilities potentially affected produce less than 2 percent of the total power produced in the region. Therefore, no substantial environmental justice effects are anticipated.

A decrease in available hydropower could result in reliance on other fuel sources for electricity generation. In California, utilities increased fossil fuel generation of electricity to compensate for the drought-driven decline in hydroelectricity, increasing state carbon dioxide emissions in the first year of the drought (2011–2012) by 1.8 million tons of carbon, the equivalent of emissions from roughly one million cars (USGCRP 2018). Other southwestern states also shifted some generation from hydropower to fossil fuels (USGCRP 2018). If water shortages resulted in the need to rely on other fuel sources, environmental justice communities could face disproportionate health impacts associated with carbon dioxide emissions; such impacts are well documented (CDC 2021; EPA 2017; USGCRP 2018).

Recreation

Potential recreational impacts are primarily associated with reduced reservoir elevations affecting access or necessitating capital alterations to shoreline facilities around Lake Powell and Lake Mead. Individuals and businesses within San Juan County, Utah, which is greater than 50 percent minority, could be affected by these recreational impacts. However, the effect would not be disproportionate to the recreational impacts experienced by other counties adjacent to Lake Powell and Lake Mead.

Socioeconomics

Under Action Alternative 1, there is potential for economic impacts from shortages to agricultural value changes, municipal water shortages, and change to recreation-based economic contributions. The locations of impacts would vary by shortage level, but would be concentrated in Arizona, with impacts, as discussed in the Water Delivery section above.

Action Alternative 2

Under Action Alternative 2, there would be a potential for impacts on a wider range of users compared with the No Action Alternative and Action Alternative 1. Impacts for other resources that could impact environmental justice communities under Action Alternative 2 would generally be similar to those described under Action Alternative 1. However, the distribution of impacts across the study area would include a wider range of users for all shortage volumes. For instance, impacts on visual resources would generally be the same under both action alternatives; however, because Action Alternative 2 would distribute water shortages across all three Lower Division States, impacts on the landscape character would be more widely distributed, but less intense (**Section 3.10.2**, Visual Resources). More information can be found in the respective resource sections.

Hydrologic Resources and Water Deliveries

Although shortages would occur at earlier levels across the environmental justice study area, the Shortage Allocation Model results indicate there would be no shortage volumes at which available water for a user would be reduced to zero. This is because, unlike Action Alternative 1, which distributes additional shortage based on priority, Action Alternative 2 distributes additional shortages based on the same percentage for all water users. As a result, it is anticipated that the potential for disproportionate impacts on environmental justice communities would be reduced compared with Action Alternative 1.

Irrigation

Under Action Alternative 2, the Shortage Allocation Model results indicate more consumptive-use impacts on irrigation across California water users, compared with the No Action Alternative and Action Alternative 1. This is because under Action Alternative 2, all six water users located within San Bernadino, Riverside, and Imperial Counties, California, would experience water shortages. For these water users, shortage contributions would increase as the total shortage volume increases. As a result, these water users would experience water shortages and consumptive-use impacts on irrigation. However, under Action Alternative 2, available water supply would not be reduced to zero at any shortage volume for California water users. Under all alternatives, shortages would not occur for irrigation water users in Nevada.

Overall, under Action Alternative 2, the Shortage Allocation Model results indicate fewer irrigation users across various Arizona priorities would experience available water supply being reduced to zero, compared with Action Alternative 1, and the same amount of users compared with the No Action Alternative. As is the case with Action Alternative 1, under Action Alternative 2, if shortages reached 400,000 af, water supply for all 5th- and 6th-priority contracts, contracts for unused CAP water, and CAP agricultural and other excess contracts (in Arizona) would not be available. The same Arizona environmental justice study areas—Pinal and Pima Counties—would be impacted.

However, unlike Action Alternative 1, available water supply for irrigation use would not be reduced to zero for any other Arizona priorities. While water shortages for irrigation use would increase for some Arizona priorities as the volume of total shortage increases, the impacts on irrigation would be less concentrated and severe, compared with Action Alternative 1.

With fewer priorities experiencing water supply reduced to zero under Action Alternative 2, compared with the other alternatives, consumptive-use impacts on irrigation would occur across fewer environmental justice study area counties. However, water users within Pima and Pinal Counties who would have water delivery reduced to zero would face disproportionate consumptive-use impacts on irrigation. Farmers who have historically relied on water allocations from the CAP and Colorado River to irrigate crops would need to use alternative water supplies, such as groundwater, if available, to continue agricultural production.

Domestic Use

Consumptive-use impacts on domestic uses would vary by the volume of the total shortage to the Lower Division States. The number of counties and different domestic water users whose water supply would be reduced would increase as the volume of total shortage to Lower Division States increased (see **Appendix D**, Shortage Allocation Model).

In California and Nevada, the environmental justice study area counties where water shortages would be experienced are the same as the No Action Alternative and Action Alternative 1 (Clark County, Nevada, and Los Angeles, Orange, San Diego, Riverside, and San Bernardino Counties, California). Under Action Alternative 2, consumptive-use impacts on domestic uses would be distributed across a wider range of water users in California and Nevada. Like under the No Action Alternative, available water supply from the CAP NIA priority for domestic use is the only supply potentially reduced to zero under Action Alternative 2 in Arizona. As is the case across alternatives, for priorities experiencing shortage, the shortage allocation generally increases as the volume of shortage increases.

If water shortages reached 400,000 af and above, water supply from the Colorado River for domestic use would be reduced for more users in Clark County, Nevada, compared with under the No Action Alternative and Action Alternative 1.

As Lake Mead's elevation decreases, the 2024 additional shortage would increase for the Lower Division States as a whole and individually.

As is the case with Action Alternative 1, if water shortages reached 1.066 maf, water supply from the CAP for domestic use would be reduced to zero for some users in Maricopa, Pinal, and Pima Counties, Arizona (all users with CAP NIA-B and CAP NIA-A priority). Water supply for these users would be reduced to zero for all subsequent shortage volume scenarios as well. Pima and Pinal Counties, Arizona, are identified as environmental justice communities. As such, the water users within these counties who would experience zero water supply would face disproportionate consumptive-use impacts on domestic uses.

Unlike Action Alternative 1, water supply from the CAP and from the Colorado River mainstream would not be reduced to zero for some users within Coconino, Gila, La Paz, Maricopa, Mohave, Pima, Pinal, and Yuma Counties. As such, consumptive use impacts on domestic uses would occur in fewer Arizona environmental justice study area counties under Action Alternative 2, compared with Action Alternative 1.

Tribal Allocations

For priorities within California and Nevada, available water supply would not be reduced to zero under any volume of total shortage. However, impacts on mainstream Tribal entitlements would increase under Action Alternative 2 compared with under Action Alternative 1 (where no shortages occur for mainstream Tribal entitlement holders under PPR). Action Alternative 2 distributes additional shortages based on the same percentage for all water users, including shortage to the mainstream Tribal entitlement holders. This is because the four entitlement-holding Tribes in California (Fort Mojave, Chemehuevi, Colorado River Indian Tribes, and Quechan) and the one Tribal entitlement holder in Nevada (Fort Mojave) would experience water shortages.

The Shortage Allocation Model results indicate some users within these communities would face increased shortage allocation under all volumes of total shortage. These entitlement holders are located within San Bernadino, Riverside, and Imperial Counties, California, and Clark County, Nevada. All of these are identified as environmental justice communities. However, because water supply would not be reduced to zero, these counties would face fewer potential disproportionate impacts due to water shortages, compared with under Action Alternative 1.

Overall, under Action Alternative 2, the Shortage Allocation Model results indicate fewer Tribes across various Arizona priorities would experience available water supply being reduced to zero. While water shortages would increase for some priorities as the volume of the total shortage increases, the impacts on Tribal allocations would be less concentrated and severe, compared with Action Alternative 1. These impacts on the Arizona environmental justice study area counties are discussed in further detail below.

As is the case for Action Alternative 1, under Action Alternative 2, if water shortages reached 1.066 maf, NIA-A priority water supply from the CAP would be reduced to zero for two Tribal communities in Maricopa, Pima, and Pinal Counties, Arizona. The same is true for these communities under all subsequent total shortage scenarios.

However, unlike under Action Alternative 1, if water shortages reached 1.734 maf and above, fourth-priority water supply from the CAP would not be reduced to zero for most contractors and subcontractors, including 7 Tribes (in Gila, Maricopa, Pima, and Pinal Counties, Arizona). If water shortages reached 1.734 maf and above, for CAP Indian priority, CAP NIA-A priority, and priority 3 CAP water supply, there would be no shortages for five Tribes. For Arizona priorities across 13 Tribes, the allocation of shortage (af) would increase as the total volume of shortage increases; however, the available water supply would not be reduced to zero.

As described in the Action Alternative 1 Tribal allocations discussion above, Pima and Pinal Counties are identified as environmental justice communities. As such, under Action Alternative 2, the water users within these counties could face temporary, disproportionate consumptive-use impacts on Tribal allocations for irrigation and domestic use. However, the available water supply being reduced to zero would be experienced by some users in fewer environmental justice counties (two), compared with the No Action Alternative and Action Alternative 1. As described in Action Alternative 1, production on Tribal lands provides an important economic base; a lack of water supply could result in reduced agricultural production and a loss of Tribal revenue. Under Action Alternative 2, the aforementioned shortages could impact on-reservation farming and could result in disproportionate impacts from losses in revenue for Tribes engaging in on-reservation farming. In this case, fewer Tribes could experience these impacts compared with Action Alternative 1.

As discussed under the Action Alternative 1 section above, shortage allocations may result in the loss of production for Tribal agricultural lands for a given year. Under Action Alternative 2, shortage allocations would be distributed in the same percentage across water users; therefore, impacts may occur on a wider range of users of all priority levels. Impacts on those Tribes holding lower-priority levels would be reduced as compared with Action Alternative 1. Those holding higher-priority rights may see a greater impact than under Action Alternative 1. Water delivery reductions may result in fallowing of some Indian lands, with the potential for economic impacts, as described above. However, annual variability in water deliveries and associated use and economic contributions would not affect the underlying settled water rights.

Cumulative Effects

The Glen Canyon Dam/Smallmouth Bass flow options would not result in any changes to disproportionate adverse health or environmental impacts. Therefore, there is no expected change in impacts on environmental justice communities.

Food production, electricity generation, and human health in the Southwest are vulnerable to water shortages. In the Southwest, severe drought, wildfire, and temperatures have increased and are anticipated to continue. Trends of population growth have impacted—and will continue to impact—the demand for water, agricultural products, electricity, and housing. These trends will contribute to cumulative effects. Environmental justice communities, including Native Americans, are among the most at risk from climate change, often experiencing the worst effects because of higher exposure, higher sensitivity, and lower adaptive capacity for historical, socioeconomic, and ecological reasons (CDC 2021; EPA 2017; USGCRP 2018).

3.18 Indian Trust Assets

3.18.1 Affected Environment

This section is summarized from Section 3.10, Indian Trust Assets, from the 2007 FEIS (Reclamation 2007) and is updated with changes since 2007. ITAs are those held in trust by the federal government for the benefit of Native American Tribes or individuals (DOI 2023a). ITAs can be on or off reservation lands and can consist of land, water rights, mineral rights, hunting and fishing rights, grazing rights, or other assets.

Reclamation is consulting with Tribes regarding the proposed changes to the 2007 Interim Guidelines, including those Tribes with water rights and water delivery contracts.

Water Rights and Trust Lands

Following the 2007 Interim Guidelines, water rights and trust lands include "federal reserved Indian rights to Colorado River water including rights established pursuant to *Arizona v. California*, Colorado River water Tribal delivery contracts where such contracts are part of a congressional approved water rights settlement; and Indian reservations" (Reclamation 2007). Reservations are treated as trust assets for the analysis, although they are not "technically synonymous with trust lands" (Reclamation 2007).

Indian Trust Assets Determined under *Arizona v. California*

Water rights of the Chemehuevi Indian Tribe, Colorado River Indian Tribes, Fort Mojave Indian Tribe, Fort Yuma-Quechan Tribe, and Cocopah Indian Tribe under the 1964 *Arizona v. California* decision and the 2006 Consolidated Decree are summarized in Table 3.10-1, Colorado River Mainstream Diversion Entitlement (Water Rights) in Favor of Indian Reservations, in Section 3.10.11 of the 2007 FEIS (Reclamation 2007).

Since the 2007 Interim Guidelines, water rights have been settled or partially settled for three additional Tribes (DOI 2023b). Water rights for the Navajo Nation in New Mexico were settled by the Northwestern New Mexico Rural Water Project Act of 2009 and for the Navajo Nation in Utah by the Navajo Utah Water Rights Settlement in 2022. The White Mountain Apache Tribe Water Rights Quantification Act of 2010 settled water rights for the White Mountain Apache Tribe. Water rights in Arizona for the Hualapai Tribe were settled under the Hualapai Tribe Water Rights Settlement Act of 2022. In addition, the Colorado River Indian Tribes' water rights in Arizona were amended with the Colorado River Indian Tribes Water Resiliency Act of 2022 to allow for the lease or exchange of water with non-reservation users within Arizona.

Central Arizona Project

Tribal Colorado River water delivered through the CAP in central Arizona is administered pursuant to water delivery contracts between Tribes and the Secretary. A summary of water rights settlements as of 2007 is presented in Section 3.10.1.2 of the 2007 FEIS (Reclamation 2007), and water rights for the CAP Tribes as of 2007 are summarized in Table 3.10-2, Central Arizona Project Indian Tribal Diversion Entitlements (Water Rights) (Reclamation 2007). As of 2023, water rights settlements involving CAP water have been executed with the Ak-Chin Indian Community, Fort

McDowell Yavapai Nation, GRIC, San Carlos Apache Tribe, Salt River Pima-Maricopa Indian Community, Tohono O'odham Nation, Yavapai-Prescott Indian Tribe, Hualapai Tribe, and White Mountain Apache Tribe. An allocation of CAP water is also set aside for the Navajo Nation.

Hydroelectric Power and Generation

The Bureau of Indian Affairs operates Headgate Rock Dam and Powerplant, which supplies electricity to the Colorado River Indian Tribes and others (Reclamation 2007). The powerplant depends on Colorado River flows; however, "Reclamation has determined that the water appropriated to non-Colorado River Indian Tribes entities that flows through Headgate Rock Dam and generates powers is not an ITA" (Reclamation 2007) and will not be further discussed in this SEIS.

Cultural and Biological Resources

No cultural or biological resources that were considered ITAs for the 2007 Interim Guidelines analysis were identified by Tribes; however, concerns were expressed regarding TCPs, archaeological sites, sacred sites, fish and wildlife, wildlife habitat, and vegetation (Reclamation 2007).

3.18.2 Environmental Consequences

Methodology

Impacts on ITAs are drawn from several sources, including water deliveries (**Section 3.7**), socioeconomics (**Section 3.16**), and cultural resources (**Section 3.11**). Water deliveries are based on the Shortage Allocation Models developed for the SEIS.

Impact Analysis Area

The impact analysis area consists of Native American Tribes with settled water rights, Native American reservations adjacent to the Colorado River, and the cultural resources analysis area (see **Section 3.10.2**).

Assumptions

The assumptions for the following analysis are:

- Changes in water allocations will not affect settled water rights.
- Previously gathered data on TCPs and Tribal concerns are sufficient.
- Tribes will supply any additional needed information.

Impact Indicators

Impact indicators for this analysis are:

- Changes in water allocations due to shortages
- Access changes to sacred sites
- Negative effects on TCPs not discussed in the 2007 FEIS or LTEMP

Issue 1: How would management of Colorado River allocations affect Tribal water rights and allocations?

Summary

Tribal water rights are a matter of settled law; however, annual water deliveries may change as a result of shortages. The projected timing and magnitude of shortages vary between the No Action Alternative and the action alternatives, but long-term water deliveries are projected to be more reliable under the action alternatives than under the No Action Alternative. The number of Tribes affected (and how they are affected) varies between Action Alternative 1 and Action Alternative 2. This is because under Action Alternative 1, water deliveries are based on priority while under Action Alternative 2, additional shortages are distributed based on the same percentage for all water users.

Water rights for individual Tribes are settled law. The determination of water allocations to individual entities is beyond the scope of this SEIS. As with the 2007 Interim Guidelines, "[n]o vested water right of any kind, quantified or unquantified, including federally reserved Indian rights to Colorado River water, rights pursuant to the Consolidated Decree or Congressionally-approved water right settlements utilizing CAP water, will be altered as a result of any of the alternatives under consideration" (Reclamation 2007). A discussion of potential impacts on Tribal agricultural lands by alternative can be found in **Section 3.17**, Environmental Justice, in this SEIS.

See also **Section 3.7**, Water Deliveries, for a full discussion of impacts on water deliveries to all parties, as well as **Appendix D**, Shortage Allocation Model Documentation.

No Action Alternative

Under the No Action Alternative, water deliveries for Tribes would follow the 2007 Interim Guidelines as analyzed in Section 4.10.1 of the 2007 FEIS (Reclamation 2007) and the DCPs. Water deliveries to Tribes would fluctuate with water availability in Lake Powell and Lake Mead, as they will fluctuate for all entities that receive water from the Colorado River. Initially, water deliveries may remain near long-term averages, but reduced deliveries would occur as lake levels decline. Any water available would be allocated by priority among and within each state. As discussed in **Section 3.17.2**, Environmental Justice, this means that CAP NIA-A priority Tribes in Arizona may have their available water reduced to zero if shortages reach a critical level. In addition, shortage allocations based on priority may result in the loss of production for Tribal agricultural lands. Any annual variability in water deliveries would not affect the underlying settled water rights.

Action Alternative 1

Under Action Alternative 1, additional shortages, including those to Tribes, would be based on priority (see **Section 3.6**, Hydrologic Resources).

Action Alternative 2

Under Action Alternative 2, additional shortages would be distributed based on the same percentage for all water users. Therefore, compared with the No Action Alternative or Action Alternative 1, water deliveries to more Tribes would be impacted when shortages occur; however, impacts on certain Tribes may be lessened.

Cumulative Effects

Reclamation has identified one past, present, and reasonably foreseeable future project that may, in conjunction with the proposed near-term Colorado River operations, contribute to cumulative effects on ITAs; this is the Glen Canyon Dam/Smallmouth Bass flow options project. Reclamation is proposing to regulate flows from the Glen Canyon Dam to control smallmouth bass populations; this will not contribute to cumulative impacts on water deliveries. No cumulative impacts on water deliveries to Tribes are anticipated.

Issue 2: How would management of Lake Powell and Lake Mead water flows and lake levels affect cultural resources or biological resources?

Summary

Previously inaccessible sacred sites would be more accessible to visitation under the No Action Alternative than under either of the action alternatives; however, the resources themselves would be more protected under the action alternatives than under the No Action Alternative. Both action alternatives would protect habitat important to riparian vegetation more than the No Action Alternative.

No Action Alternative

Under the No Action Alternative, decreases in the pool elevations at Lake Powell and Lake Mead and lower river levels during times of low releases may increase visitor access to sacred sites that were previously inaccessible, under water, or buried under river sediment (see **Section 3.11.2**, above). Native plant species' habitat would decrease while nonnative species' habitat would increase (see **Section 3.13.2**, above). Vegetation is an important element of TCPs important to Native Americans.

Action Alternative 1

Under Action Alternative 1, decreases in the pool elevation at Lake Powell and Lake Mead and lower river levels during times of low releases could increase visitor access to sacred sites, but to a lesser degree than under the No Action Alternative (see **Section 3.11.2**, above).

Action Alternative 1 would result in increases in riparian vegetation in Marble Canyon and eastern Grand Canyon. Riparian vegetation would decline in the western Grand Canyon (see **Section 3.13.2**, above).

Action Alternative 2

Impacts under Action Alternative 2 would be the same as described under Action Alternative 1.

Cumulative Effects

Reclamation has identified one past, present, and reasonably foreseeable future project that may, in conjunction with the proposed near-term Colorado River operations, contribute to cumulative effects on ITAs; this is the Glen Canyon Dam/Smallmouth Bass flow options project. Reclamation is proposing to regulate flows from the Glen Canyon Dam to control smallmouth bass populations. The proposed releases are within the previously approved flows under the LTEMP, but they may impact TCPs important to Native Americans. Adverse effects on TCPs, as historic properties, will be resolved under the LTEMP PA, land management agency actions, and the nonnative fish MOA in development. These effects should not contribute to cumulative impacts.

Adverse effects on TCPs are not anticipated from the proposed near-term Colorado River operations; however, if adverse effects are present, they will be resolved either under the LTEMP PA or Section 106 of the NHPA process; therefore, the proposed near-term Colorado River operations will not contribute to cumulative impacts on ITAs.

Chapter 4. Consultation and Coordination

4.1 Introduction

This chapter describes Reclamation's public involvement program and coordination with specific federal, state, and local agencies, along with Tribal consultations.

4.2 General Public Involvement Activities

The public involvement program leading to this draft SEIS included project scoping, consultation, and coordination with Tribes, agencies, stakeholders, and the public. Reclamation developed and implemented a public involvement plan to satisfy the public participation requirements set forth in NEPA and to establish a consistent and constant level of engagement with interested parties and stakeholders. The multifaceted approach consisted of informational materials, consultation and coordination meetings, general and stakeholder outreach, and media relations.

A variety of informational materials to educate and inform audiences about the study and related issues were employed. A website was established and maintained for this SEIS. It contained project documents, points of contact, and the project schedule. An electronic mailing list was used to notify interested parties of website postings, project meetings, and documents. A project email account was maintained live during the entire period of preparing this SEIS for interested parties to express opinions, ask questions, and submit comments.

Reclamation published a NOI to prepare an SEIS and a modified Record of Decision for the 2007 Interim Guidelines in the *Federal Register* on November 17, 2022. A 30-day scoping comment period was held from November 17, 2022, to December 20, 2022. Reclamation notified interested parties of the NOI and scoping comment period through an email notification to the project mailing list on December 1, 2022. The email consisted of a NOI and two public webinars.

Reclamation held two virtual public webinars during the scoping period. One meeting was held on November 29, 2022, from 10:00 a.m. to noon mountain standard time, and 184 people attended. The second virtual public meeting was held on December 2, 2022, from 11:00 a.m. to 1:00 p.m. mountain standard time, and 241 people attended. The webinars included an opening statement, a presentation that summarized the NOI, a range of hydrology and operations scenarios that informed people about the SEIS analysis, an overview of potential alternatives being considered in the SEIS, information on the SEIS process schedule, and a question-and-answer session. The webinars were recorded and published on the project website.[1] Public comments were accepted during the comment period by email and mail. A scoping summary report was prepared to summarize all public comments received during scoping. Reclamation made the public scoping comments and the scoping summary report available for public viewing in an accessible format on the project website.

[1] https://www.usbr.gov/ColoradoRiverBasin/SEIS.html

The draft SEIS is available for public review on the project website. Reclamation will hold several virtual open house meetings to provide opportunities to learn more about the project, provide analysis, speak with Reclamation managers and resource specialists, ask questions, and provide comments. Public comments will be accepted for 45 calendar days following the US Environmental Protection Agency's publication of the Notice of Availability in the *Federal Register*. Comments may be provided by email to CRinterimops@usbr.gov or by mail to Reclamation 2007 Interim Guidelines SEIS Project Manager, Upper Colorado Basin Region, 125 South State Street, Suite 8100, Salt Lake City, Utah 84138.

4.3 Cooperating Agency Involvement

In compliance with NEPA and its implementing regulations, Reclamation worked with five cooperating agencies in the preparation of this SEIS. As described in **Chapter 1**, cooperating agencies included the BIA, the Service, the NPS, WAPA, and the USIBWC. In developing the draft SEIS, Reclamation hosted seven cooperating agency virtual meetings to obtain data, information, resource analysis, and review of internal documents. Additionally, individual agencies provided specific assistance, including the following:

- The BIA administers the federal trust responsibility to Indian Tribes.
- The Service has jurisdiction by law and special expertise with respect to the ESA and biological resources within the study area and its administration of several wildlife refuges in the study area. The Service provided resource expertise, and they worked closely with Reclamation in development of two biological assessments to support consultation under Section 7 of the ESA.
- Given their jurisdiction of NPS Units within the Basin and administration of recreation on Lake Powell and Lake Mead, the NPS provided data and analysis of potential impacts to resources under their management.
- The WAPA provided hourly release volume models for Glen Canyon Dam to aid in resource-specific modeling. The WAPA also provided hydroelectric modeling to assess impacts to power generation and revenue across the major generation facilities in the Upper and Lower Basin.
- The USIBWC provided guidance and reviewed internal documents to ensure the SEIS adequately addressed treaty obligations and international commitments. The USIBWC has worked with Reclamation to ensure that Mexico has been kept informed of all permissibly available information regarding the SEIS process.

While not a cooperating agency, the USGS also contributed expertise and resource modeling support.

4.4 Tribal Consultation and Coordination

For purposes of this NEPA process, Reclamation is consulting and coordinating with Tribes who have entitlements to or contracts for Colorado River water and those that may be affected by or have interests in the proposed federal action. Representatives of various Indian Tribes also attended the scoping meetings in November and December 2022. Eighteen Tribes provided Reclamation with written comments on the proposed federal action and its potential effects on resources of Tribal concern, including ITAs.

4.4.1 Summary of Tribal Consultation and Coordination

There are many federally recognized Tribes with entitlements to or contracts for Colorado River water or who may be affected or have interests in the proposed federal action. There are 30 federally recognized Tribes within the geographic Basin. Reclamation consults regularly with these Tribes regarding Colorado River issues. These Tribes are listed in **Table 4-1** and shown in **Map 4-1**.

Table 4-1
Basin Tribes

- Ak-Chin Indian Community
- Chemehuevi Indian Tribe
- Cocopah Indian Tribe
- Colorado River Indian Tribes
- Fort McDowell Yavapai Nation
- Fort Mojave Indian Tribe
- Gila River Indian Community
- Havasupai Tribe
- Hopi Tribe
- Hualapai Indian Tribe
- Jicarilla Apache Nation
- Kaibab Band of Paiute Indians
- Las Vegas Tribe of Paiute Indians
- Moapa Band of Paiute Indians
- Navajo Nation
- Paiute Indian Tribe of Utah
- Pascua Yaqui Tribe
- Quechan Indian Tribe
- Salt River Pima-Maricopa Indian Community
- San Carlos Apache Tribe
- San Juan Southern Paiute
- Southern Ute Indian Tribe
- Tohono O'odham Nation
- Tonto Apache Tribe
- Ute Indian Tribe of the Uintah and Ouray Reservation
- Ute Mountain Ute Tribe
- White Mountain Apache Tribe
- Yavapai-Apache Nation
- Yavapai-Prescott Indian Tribe
- Zuni Tribe

The Ten Tribes Partnership is a coalition of 10 federally recognized Tribes with rights and unresolved claims to Colorado River water. The partnership was created in 1992 and it has an ongoing consultation relationship with Reclamation. Federally recognized Tribes of the Ten Tribes Partnership are listed in **Table 4-2**.

Table 4-2
Ten Tribes Partnership Tribes

- Ute Mountain Ute Tribe
- Southern Ute Indian Tribe
- Ute Indian Tribe of the Uintah and Ouray Reservation
- Jicarilla Apache Nation
- Navajo Nation
- Fort Mojave Indian Tribe
- Colorado River Indian Tribes
- Chemehuevi Indian Tribe
- Quechan Indian Tribe
- Cocopah Indian Tribe

Of the 22 federally recognized Tribes in Arizona, 14 have fully resolved, adjudicated rights, or partially resolved rights to water from the Colorado River. A significant portion of that water is provided through the CAP. Reclamation has a long-standing and ongoing consultation relationship with Tribes receiving Colorado River water through the CAP. **Table 4-3** lists CAP Tribes.

Table 4-3
CAP Tribes

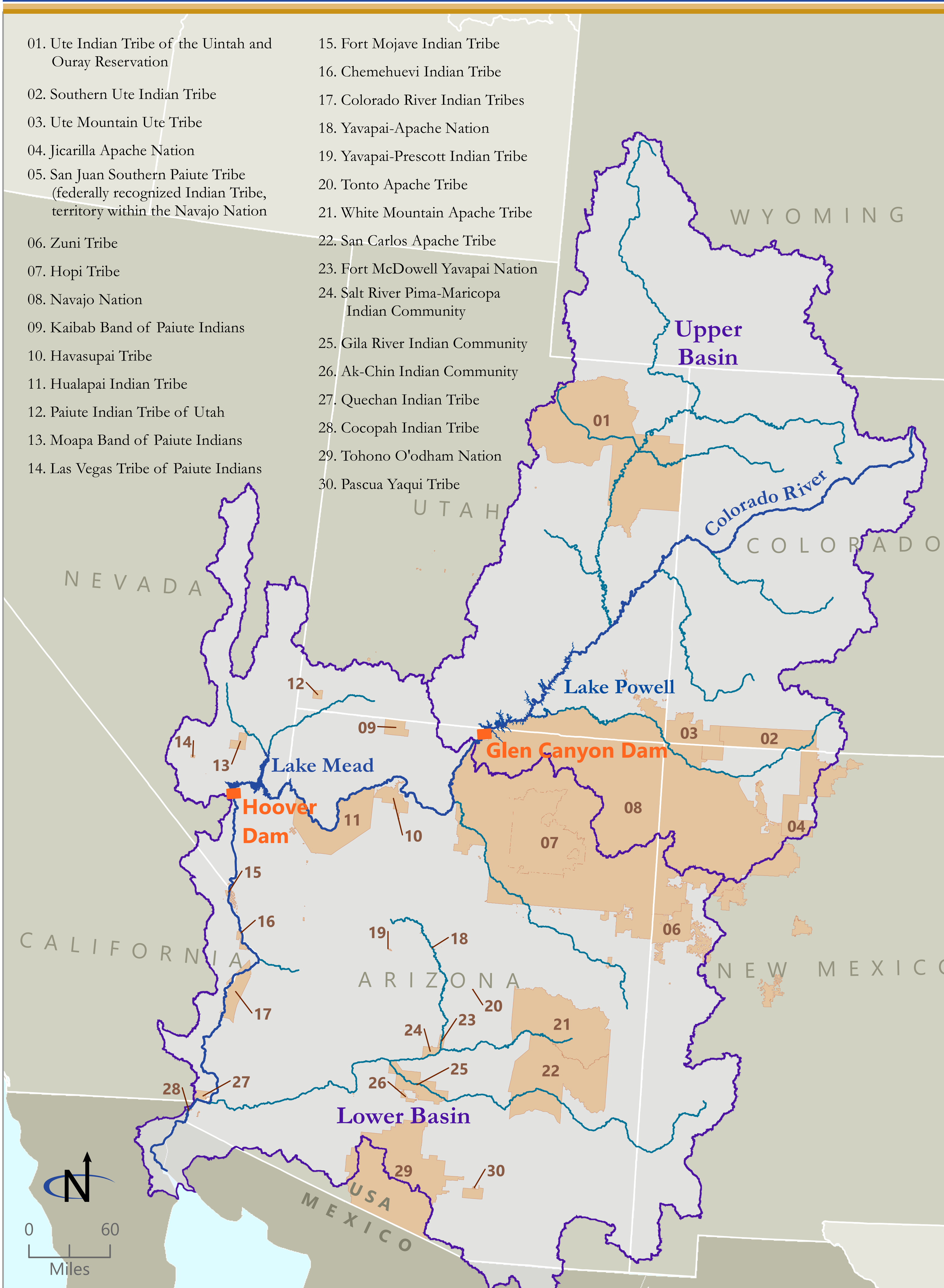
• Ak-Chin Indian Community	• San Carlos Apache Tribe
• Fort McDowell Yavapai Nation	• Tohono O'odham Nation
• Gila River Indian Community	• Tonto Apache Tribe
• Hualapai Tribe	• White Mountain Apache Tribe
• Pascua Yaqui Tribe	• Yavapai-Apache Nation
• Salt River Pima-Maricopa Indian Community	• Yavapai-Prescott Tribe

Reclamation consults not only with Tribes who hold water rights or are located within the geographic boundary of the Basin, but also Tribes who may be affected or have interests in actions on the Colorado River. **Table 4-4** lists the 43 federally recognized Tribes with whom Reclamation consults on issues regarding the Colorado River.

Table 4-4
Tribes Consulted on Colorado River Issues

• Ak-Chin Indian Community	• Pueblo of Pojoaque
• Chemehuevi Indian Tribe	• Pueblo of San Felipe
• Cocopah Tribe of Arizona	• Pueblo of San Juan
• Colorado River Indian Tribes	• Pueblo of Sandia
• Fort McDowell Yavapai Nation	• Pueblo of Santa Ana
• Fort Mojave Indian Tribe	• Pueblo of Santa Clara
• Gila River Indian Community	• Pueblo of Tesuque
• Havasupai Indian Tribe	• Pueblo of Zia
• Hopi Tribe	• Quechan Indian Tribe
• Hualapai Indian Tribe	• Salt River Pima-Maricopa Indian Community
• Jicarilla Apache Nation	• San Carlos Apache Tribe
• Kaibab Band of Paiute Indians	• San Juan Southern Paiute Tribe
• Las Vegas Tribe of Paiute Indians	• Southern Ute Indian Tribe
• Moapa Band of Paiute Indians	• Tohono O'odham Nation
• Navajo Nation	• Tonto Apache Tribe
• Paiute Indian Tribe of Utah	• Ute Indian Tribe of the Uintah and Ouray Reservation
• Pascua Yaqui Tribe	• Ute Mountain Ute Tribe
• Pueblo of Acoma	• White Mountain Apache Tribe
• Pueblo of Cochiti	• Yavapai-Apache Nation
• Pueblo of Jemez	• Yavapai-Prescott Tribe
• Pueblo of Laguna	• Zuni Tribe
• Pueblo of Nambe	

BUREAU OF RECLAMATION



Map 4-1 Colorado River Basin Tribes

Tribal Reservation and off-reservation trust land

Colorado River

Colorado River tributary

Dam

Colorado River Basin, Upper and Lower Basins

States in the Colorado River Basin

Source: National Weather Service GIS. 2023, Reclamation GIS 2023, USGS National Hydrography Dataset GIS. 2023; Map production: U.S. Department of the Interior, Bureau of Reclamation, Upper and Lower Colorado Basin Regions; Date: March 25, 2023, Disclaimer: This map is intended for informational purposes only. Geographic features may have been compiled at varying scales and for different purposes. No representation is made as to the accuracy of this graphic.

This page intentionally left blank.

4.4.2 Tribal Consultation Efforts

An NOI to prepare this SEIS was published in the *Federal Register* on November 17, 2022. Since that date, Reclamation has engaged regularly with the Tribes described above. **Table 4-5** provides a summary of those Tribal consultation and coordination efforts conducted by Reclamation between publication of the NOI and April 1, 2023.

Table 4-5
Summary of Tribal Consultation Efforts

Date	Meeting Title/Subject of Correspondence	Purpose	Tribes Invited
11/17/2022	Basin Tribal Information Exchange	Monthly meeting	Tribal leaders and representatives for Tribes throughout the Basin
11/22/2022	SEIS NOI Publication and Public Scoping Webinar Information Email Notification	Email communicating the Department's SEIS NOI publication in the *Federal Register* on November 17, 2022, and sharing of the upcoming scoping webinar information for the SEIS	Tribal leaders and representatives for Tribes throughout the Basin
11/23/2022	SEIS NOI Publication and Public Scoping Webinar Information Email Notification	Email communicating the Department's SEIS NOI publication in the *Federal Register* on November 17, 2022, and sharing of the upcoming scoping webinar information for the SEIS	San Juan-Chama project stakeholders
11/28/2022	SEIS NOI Publication, Purpose, and Public Scoping Process Correspondence	Letter from regional directors communicating the Department's SEIS NOI publication in the *Federal Register* on November 17, 2022, its purpose, and information on the scoping process for the SEIS	Tribal leaders for Tribes throughout the Basin
12/9/2022	Inter-Tribal Council of Arizona (ITCA) Tribal Leaders Water Policy Council and Colorado River Tribal Roundtable Meeting	Special ITCA meeting with all Basin Tribal leaders to provide an update on the SEIS NOI and scoping and an update on the post-2026 process	The ITCA extended an invitation outside of Arizona to all Tribal leaders and representatives for Tribes throughout the Basin.

Date	Meeting Title/Subject of Correspondence	Purpose	Tribes Invited
12/14/2022	Quechan Indian Tribe Meeting	Meeting with the Department and Reclamation leadership to discuss current issues on the Basin, including the SEIS scoping process and relevant information	Quechan Indian Tribe
12/15/2022	Ten Tribes Partnership Meeting	Bimonthly meeting with member Tribes of the Ten Tribes Partnership	Ten Member Tribes of the Ten Tribes Partnership
12/15/2022	Upper Basin Tribe Meeting	Meeting with Department and Reclamation leadership to discuss current issues on the Basin, including the SEIS scoping process and relevant information	Jicarilla Apace Nation, Navajo Nation, Paiute Indian Tribe of Utah, Southern Ute Indian Tribe, Ute Indian Tribe, and Ute Mountain Ute Tribe
12/15/2022	Navajo Nation Meeting	Meeting with Department and Reclamation leadership to discuss current issues on the Basin, including the SEIS scoping process and relevant information	Navajo Nation
12/15/2022	Ute Mountain Ute Tribe Meeting	Meeting with Department and Reclamation leadership to discuss current issues on the Basin, including the SEIS scoping process and relevant information	Ute Mountain Ute Tribe
12/15/2022	Colorado River Indian Tribes Meeting	Meeting with Department and Reclamation leadership to discuss current issues on the Basin, including the SEIS scoping process and relevant information	Colorado River Indian Tribes
12/15/2022	Jicarilla Apache Nation Meeting	Meeting with Department and Reclamation leadership to discuss current issues on the Basin, including the SEIS scoping process and relevant information	Jicarilla Apache Nation
12/15/2022	Ute Indian Tribe Meeting	Meeting with Department and Reclamation leadership to discuss current issues on the Basin, including the SEIS scoping process and relevant information	Ute Indian Tribe of the Uintah and Ouray Reservation

Date	Meeting Title/Subject of Correspondence	Purpose	Tribes Invited
12/15/2022	Gila River Indian Community Consultation	The Gila River Indian Community requested government-to-government consultation to discuss the SEIS scoping process; relevant information to the SEIS process, such as hydrologic updates; and other system conservation offers.	Gila River Indian Community
12/15/2022	Southern Ute Indian Tribe Consultation	Meeting with Department and Reclamation leadership to discuss current issues on the Basin, including the SEIS scoping process and relevant information	Southern Ute Indian Tribe
1/13/2023	Southern Ute Indian Tribe Consultation	The Southern Ute Indian Tribe Council requested a meeting with Upper Basinregional leadership to discuss the contents of the Southern Ute Indian Tribe's SEIS scoping comment letter.	Southern Ute Indian Tribe
1/19/2023	Basin Tribal Information Exchange	Monthly meeting	Tribal leaders and representatives for Tribes throughout the Basin
2/8/2023	Ten Tribes Partnership Meeting	Bimonthly meeting with member Tribes of the Ten Tribes Partnership	Ten Member Tribes of the Ten Tribes Partnership
3/7/2023	SEIS Process and Tribal Consultation Timeline Correspondence	Letter from regional directors communicating Reclamation's planned timeline and process for government-to-government consultation on the draft SEIS	Tribal leaders and representatives for Tribes throughout the Basin
3/17/2023	Upper Basin Tribes-States Dialogue Meeting	Reclamation invited to participate in semi-regular meeting between Upper Basin Tribes and States	Leaders and representatives of the six Upper Basin Tribes
3/23/2023	Basin Tribal Information Exchange	Monthly meeting	Tribal leaders and representatives for Tribes throughout the Basin

4.5 Endangered Species Act Section 7 Consultation

The ESA Section 7 interagency consultations (16 USC 1531) were initiated with the Service in January 2023. They continued through a series of meetings and email exchanges during which listed species were identified, actions and action areas were discussed, and conservation measures were developed. Two biological assessments were developed, one for the Lower Colorado River[2] in relation to the Multi-Species Conservation Program, and one for the Upper Colorado River[3] in relation to the LTEMP. Additional coordination is being conducted between Reclamation and the Lower Basin States to ensure compliance with the existing Habitat Conservation Plan and future actions. Consultation is ongoing with an anticipated finalization of two biological opinions in July 2023.

[2] From Lake Mead to the SIB
[3] Lake Powell, Glen Canyon Dam, and the Colorado River downstream to Lake Mead

List of Preparers

The Draft SEIS was prepared by Reclamation with resource modeling and analysis support from the National Park Service, Northern Arizona University, US Geological Survey, and Western Area Power Administration. This is a list of preparers who developed significant background material and various sections or they participated, to a significant degree, in the preparation of this Draft SEIS.

Bureau of Reclamation Team

Name	Project Role
Genevieve Johnson	Project Manager/Team Co-Lead
Jacklynn (Jaci) Gould	Lower Colorado Basin Regional Director
Wayne Pullan	Upper Colorado Basin Regional Director
Katrina Grantz	Deputy Regional Director
Dan Bunk	Boulder Canyon Operations Office Chief
Marcie Bainson	Team Co-Lead
Amanda Erath	Core SEIS/Strategy Team
Amy Witherall	Core SEIS/Strategy Team
Carly Jerla	Core SEIS/Strategy Team
Chris Cutler	Core SEIS/Strategy Team
Mike Beckemeyer	Core SEIS/Strategy Team
Kathleen Callister	NEPA Team - NHPA Lead
Mike Boyles	NEPA Team - Team Lead
Rick Baxter	NEPA Team
Sean Heath	NEPA Team
Toshi Yoshida	NEPA Team
Deanna Morrell	Administration Team
Dedina Williams	Administration Team
Meghan Thiemann	Administration Team - Co-Lead
Sherie Jaramillo	Administration Team - Budget
Stephanie Powers	Administration Team - Budget
Alan Butler	Hydrology and Modeling Team - Team Co-Lead
Alex Pivarnik	Hydrology and Modeling Team
Jessica Khaya	Hydrology and Modeling Team
Jim Prairie	Hydrology and Modeling Team - Team Co-Lead
Rebecca Smith	Hydrology and Modeling Team
Sarah Baker	Hydrology and Modeling Team
Val Deppe	Hydrology and Modeling Team
Jimmy Knowles	ESA Team – Team Lead
Kerri Pedersen	ESA Team
William Stewart	ESA Team
Ernie Rheaume	NHPA and Tribal Consultation Team – Co-Lead

Name	Project Role
Justin DeMaio	NHPA and Tribal Consultation Team
KayLee Nelson	NHPA and Tribal Consultation Team – Team Lead
Lawrence Marquez	NHPA and Tribal Consultation Team
Zac Nelson	NHPA and Tribal Consultation Team
Becki Bryant	Communications and IT Team - Team Lead, Public Affairs
Michelle Helms	Communications and IT Team - Public Affairs
Jeremy Brooks	Contracting Officer's Representative
Troy Ethington	GIS Lead
Mike Bernardo	Lower Basin Operations
Lesli Kirsch	Economist

Partner Agencies

Name	Agency	Role
Catherine Wilson	BIA	Tribal Water Rights
Chip Lewis	BIA	NEPA/Biological Resources
Garry Cantley	BIA	Cultural Resources
Mary Barger	BIA	Cultural Resources
Ray Roessel	BIA	Hydrology
Brett Meldrum	NPS	Socioeconomics and Recreation
Lisa Devore	NPS	Air Quality
Lynne Koontz	NPS	Socioeconomics and Recreation
Melissa Trammell	NPS	Fish
Rob Billerbeck	NPS	Recreation, Socioeconomics, Natural and Cultural Resources
Paul Larson	NPS - CLNP	GCNRA Recreation (Upstream)
Steve Young	NPS - CLNP	GCNRA Recreation (Upstream)
Brandon Holton	NPS - GCNP	Threatened and endangered birds and other wildlife
Elyssa Shalla	NPS - GCNP	Recreation and Socioeconomics
Emily Omana	NPS - GCNP	Fish
Greg Holmes	NPS - GCNP	Threatened and endangered birds and other wildlife
Jan Balsom	NPS - GCNP	Recreation
Jen Dierker	NPS - GCNP	Cultural resources
Michael Kearsley	NPS - GCNP	Recreation
Miranda Terwillinger	NPS - GCNP	Threatened and endangered birds and other wildlife
Amy Schott	NPS - GCNRA	Cultural Resources
Buddy Fazio	NPS - GCNRA	Natural and Cultural Resources
Heidie Grigg	NPS - GCNRA	Recreation and Socioeconomics

Name	Agency	Role
Kendall Neisess	NPS - GCNRA	Recreation and Socioeconomics
Mark Sappington	NPS - LMNRA	Water and Air Quality
Michelle Kerns	NPS - GCNRA	Recreation and Socioeconomics
Taryn Preston	NPS - GCNRA	Natural and Cultural Resources
Vanessa Glynn-Linaris	NPS - GCNRA	Air Quality
Mike Gauthier	NPS - LMNRA	Recreation and Socioeconomics
Jodi Bailey	NPS - LMNRA	Recreation and Socioeconomics
Chris Nycz	NPS - LMNRA	Cultural Resources
Bradley Butterfield	Northern Arizona University	Riparian vegetation modeling
A J Vale	Service	Fish and wildlife
Dan Leavitt	Service	Fish and wildlife
Jeff Servoss	Service	Fish and wildlife
Jess Newton	Service	Fish and wildlife
Julie Crawford	Service	Fish and wildlife
Kirsty Bramlett	Service	Fish and wildlife
Mark Lamb	Service	Fish and wildlife
Melissa Mata	Service	Fish and wildlife
Nichole Engelmann	Service	Fish and wildlife
Rebecca Chester	Service	Fish and wildlife
Scott Richardson	Service	Fish and wildlife
Bridget Deemer	USGS Grand Canyon Monitoring and Research Center	Water quality modeling
Bryce Mihalevich	USGS Grand Canyon Monitoring and Research Center	Water quality modeling
Charles Yackulic	USGS Grand Canyon Monitoring and Research Center	Fisheries modeling
Drew Eppehimer	USGS Grand Canyon Monitoring and Research Center	Fisheries modeling
Emily Palmquist	USGS Grand Canyon Monitoring and Research Center	Riparian vegetation modeling
Gerard Salter	USGS Grand Canyon Monitoring and Research Center	Sediment modeling
Joel Sankey	USGS Grand Canyon Monitoring and Research Center	Cultural (sediment) modeling
Lucas Bair	USGS Grand Canyon Monitoring and Research Center	Recreation impact modeling
Adrian Cortez	USIBWC	International considerations
Jennifer Peña	USIBWC	International considerations
Sally Spener	USIBWC	International considerations
Clayton Palmer	WAPA	Upper Basin hydroelectric generation and economic modeling
Jerry Wilhite	WAPA	Upper Basin hydroelectric generation and economic modeling

Name	Agency	Role
John Paulsen	WAPA	Lower Basin economic modeling
Xavier Gonzalez	WAPA	Lower Basin hydroelectric generation modeling

Contractor Technical Team and Support Staff

Name	Education	Experience (years)	Project Role
Prime Contractor – EMPSi: Environmental Management and Planning Solutions, Inc.			
Amy Cordle	BS, Civil Engineering	26	Climate Change
Amy Lewis	MS, Environmental Science	26	NEPA Specialist
Andy Spellmeyer	MS, Biology	8	508 Compliance
Bronson Pace	Ph.D., Water Resources: Law, Management, and Policy	3	QA/QC
Camila Reiswig	MS, Agriculture and Applied Economics	10	Agricultural and Energy Economics
Chelsea Ontiveros	MS, Geographic Information Systems Technology	2	GIS
David Batts	MS, Natural Resource Management	30	Project Manager
David Scott	BS, Environmental Science,	5	Hydrology Lead/Hydropower
Katie Patterson	JD, Environmental Law	12	Deputy Project Manager
Kevin Doyle	BA, Sociology	37	NEPA Lead
Kirsten Davis	BS, Environmental Science	4	Transportation
Marcia Rickey, GISP	MS, Biology	21	GIS Lead
Megan Stone	BA, Environmental Studies	5	Environmental Justice
Noelle Crowley	MENV, Sustainability Planning and Management	4	Recreation
Shine Roshan	MS, Physics	4	Socioeconomics
Taylor Bartlett	BA, Environmental Science	2	Information Manager/ Bibliography Lead
Valerie Stanson	MPH, Environmental Health	3	Water Resources
Zoe Ghali	MS, Integrative Physiology	14	Socioeconomics/ Environmental Justice Lead
Subcontractor - SWCA			
Adrian Hogel	MS, Ecology	17	Vegetation
Adrienne Tremblay	Ph.D., Anthropology	17	Cultural Resources
Alexandra Shin	MS, Env. Policy and Management	10	Public Agency and Coordination Team Lead/ Comment Management
Amanda Nicodemus	MS, Biology	20	Technical Team Lead
Erin Wielenga	BS, Botany	12	Air Quality
Jill Grams	MLA, Landscape Architecture	25	NEPA Advisor

Name	Education	Experience (years)	Project Role
Kelly Beck	Ph.D., Anthropology	21	Section 106/Tribal Coordination Lead
Kevin Rauhe	BLA, Landscape Architecture	10	Visual Resources
Mary Anne McLeod	MS, Wildlife Conservation	30	Section 7/Avian Species
Matt Westover	MS, Wildlife and Wildlands Conservation	10	Biologist Lead
Meg Perry	MEM, Ecosystem Science and Conservation	12	Public Involvement Support
Randa Horton	BS, Environmental Studies	15	Indian Trust Assets/Section 106 Support
Rich Valdez, CFS	Ph.D., Fisheries Ecology	52	Section 7/Fisheries
Stephanie Graham	MS, Wildlife Biology	17	Section 7/Biological Assessment Lead
Stephanie Trapp	MS, Wildlife Science	7	Wildlife/Special Status Species
Stephen Zipper	MS, Natural Resources	13	Fisheries
Suzanne Griset	Ph.D., Anthropology	44	Section 106 Tribal Coordination Support
Subcontractor - Hazen and Sawyer			
Angela Bacigalupa, PE, ENV SP	BS, Environmental Engineering	9	Hydrology/Water Deliveries
Diane Roher, PE	MS, Environmental Engineering	6	Hydrology/Water Deliveries
Elizabeth Crafton	Ph.D., Civil Engineering	9	Hydrology/Water Quality
Greg Gates, PE	MS, Environmental Health Engineering	30	Expert Scientist/Engineer
Luke Wang, PE	MS, Earth and Environmental Engineering	12	Database Manager
Melissa Estep	MS, Civil Engineering	11	Hydrology
Other Subcontractors			
Jeff Lukas	MS, Forestry	25	Climate Change
Robert Thomson	MS, Ecology	45	Senior NEPA Advisor
Kevin Wheeler, PE	Ph.D., Transboundary Water Management	22	Hydrologist

This page intentionally left blank.

References

8NewsNow. 2022. Hoover Dam power production down 33%, official says. Internet website: https://www.8newsnow.com/news/local-news/hoover-dam-power-production-down-33-official-says/.

Albrecht, B., H. E. Mohn, R. B. Kegerries, M. C. McKinstry, R. Rogers, T. A. Francis, B. Hines, et al. 2017. Use of inflow areas in two Colorado River Basin reservoirs by the endangered razorback sucker (*Xyrauchen texanus*). Western North American Naturalist 77(4):500-514.

Arizona Department of Environmental Quality. 2022. Feasibility Study Lake Havasu Avenue and Holly Avenue Water Quality Assurance Revolving Fund Site Lake Havasu City, Arizona. Internet website: https://static.azdeq.gov/wqarf/havasu_holly_fs22.pdf.

AZ Central. 2015. $40M Glen Canyon Dam turbine replacement almost done. Internet website: https://www.azcentral.com/story/news/local/arizona/2015/07/12/feds-close-wrapping-replacement-dam-turbines/30043705/.

Baker, B. 2022. "Glen Canyon's side canyons spring back to life: A Q&A with an ecologist on how Glen Canyon is returning as Lake Powell recedes". *The Salt Lake City Tribute*. Internet website: https://www.sltrib.com/news/environment/2022/08/28/glen-canyons-side-canyons-spring/.

Bestgen, K. R., and A. A. Hill. 2016. River regulation affects reproduction, early growth, and suppression strategies for invasive smallmouth bass in the upper Colorado River basin. Final report submitted to the Upper Colorado River Endangered Fish Recovery Program, Denver, Colorado. Department of Fish, Wildlife, and Conservation Biology, Colorado State University, Fort Collins. Larval Fish Laboratory Contribution 187.

Blommer, G. L., and A. W. Gustaveson. 2021. Lake Powell Fisheries Investigations Completion Report May 2015 – April 2020. Sport Fish Restoration Act. Project F-46 R. Utah Department of Natural Resources, Salt Lake City, Utah.

Bloome, D. W., E. De Guzman, and S. Jaeckel. 2016. Transferring Lessons From Australia's Millennium Drought To California: Accelerating Adaptation To Drought, Flood & Heat. Tree People.

Bonde, A. and M. Slaughter. 2020. Paleontological Resources Inventory of the Lower Colorado Region. US Department of the Interior, Bureau of Reclamation, Lower Colorado Region, Boulder City, Nevada. November.

Bureau of Economic Analysis. 2023a. CAEMP25N Total full-time and part-time employment by NAICS industry. Washington, D.C. Internet website: https://apps.bea.gov/itable/.

______. 2023b. CAINC5N Personal income by major component and earnings by NAICS industry. Washington, D.C. Internet website: https://apps.bea.gov/itable/.

Bureau of Land Management (BLM). 2014. Bureau of Land Management Special Status Animal Species by Field Office. California. US Department of the Interior.

______. 2017a. Bureau of Land Management Nevada Sensitive Status Species list. US Department of the Interior.

______. 2017b. Bureau of Land Management, Arizona – Bureau Sensitive Species List (February 2017). US Department of the Interior.

______. 2018. Utah Bureau of Land Management Sensitive Wildlife Species List. December 2018. US Department of the Interior.

Bureau of Reclamation (Reclamation). 2004. Lower Colorado River Multi-Species Conservation Program. Final Habitat Conservation Program. Volume II. December 17, 2004. Internet website: Volume II: Final Habitat Conservation Plan (lcrmscp.gov). Accessed January 2023.

______. 2007. Colorado River Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lake Powell and Lake Mead–Final Environmental Impact Statement. November 2007. Internet website: https://www.usbr.gov/lc/region/programs/strategies/FEIS/index.html.

______. 2019a. CRSEIS request20230203160701 contaminant monitoring data for Lake Havasu and LCRCMP.

______. 2019b. Exhibit 1 to the Lower Basin Drought Contingency Plan Agreement. Internet Website: https://www.usbr.gov/dcp/docs/final/Attachment-B-Exhibit-1-LB-Drought-Operations.pdf.

______. 2020a. Review of the Colorado River Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lake Powell and Lake Mead.

______. 2020b. Annual Operating Plan for Colorado River Reservoirs 2020.

______. 2020c. Warren H. Brock Reservoir Conservation Summary Report. Internet website: https://www.usbr.gov/lc/region/g4000/4200Rpts/DecreeRpt/2020/33.pdf.

______. 2021a. Reclamation to begin dredging work upstream of Imperial Dam. Internet website: https://www.usbr.gov/newsroom/newsroomold/newsrelease/detail.cfm?RecordID=73652.

______. 2021b. Colorado River Basin Impacts of Drought on Hydropower. Internal Report.

______. 2021c. Annual Operating Plan for Colorado River Reservoirs 2021.

______. 2021d. Long Term Experimental and Management Plan Riparian Vegetation Project Plan. For the implementation of the vegetation environmental commitments from the LTEMP ROD in Glen Canyon National Recreation Area and Grand Canyon National Park Below Glen Canyon Dam. February 19, 2021. Internet website: https://www.usbr.gov/uc/progact/amp/twg/2021-04-14-twg-meeting/20210414-DraftRiparianVegetationProjectPlan-508-UCRO.pdf.

______. 2022a. Colorado River Basin Salinity Control Program. Internet website: https://www.usbr.gov/uc/progact/salinity/.

______. 2022b. Colorado River Basin Salinity Control Program. Internet website: https://www.usbr.gov/uc/progact/salinity/.

______. 2022c. Colorado River Basin Natural Flow Data. Internet website: https://www.usbr.gov/lc/region/g4000/NaturalFlow/provisional.html.

______. 2022d. CRBS Supply Use Data from June 2022.

______. 2023a. Reclamation Information Sharing Environment (RISE). Internet website: https://data.usbr.gov/.

______. 2023b. Parker-Davis Project. Internet website: https://www.usbr.gov/projects/index.php?id=377.

______. 2023c. Analysis of impacts on marsh and open water vegetation. Unpublished data.

______. 2023d. Glen Canyon Dam. Retrieved from Upper Colorado Region. Internet website: https://www.usbr.gov/uc/water/crsp/cs/gcd.html.

______. 2023e. Lees Ferry Annual Natural Flow Data from January 2023.

______. 2023f. Lake Mead Elevation Data from January 2023. Internet website: https://www.usbr.gov/lc/region/g4000/lakemead_line.pdf.

______. 2023g. Modeling Results from 2023, CRMSS.

Bureau of Reclamation (Reclamation) and National Park Service (NPS). 2016. Glen Canyon Dam Long-Term Experimental and Management Plan–Final Environmental Impact Statement. October 2016. Prepared by Bureau of Reclamation and National Park Service. Internet website: https://ltempeis.anl.gov/documents/final-eis/.

Burns, J., A. Horn, K. Spurr, and J. Hagopian. 2022. Final report on condition assessments at archeological sites in the Lake Canyon Grazing Allotment and Lakeshore Areas within Glen Canyon National Recreation Area, Utah. Glen Canyon National Recreation Area/Rainbow Bridge National Monument Cultural Resources Report 2022-005. Utah SHPO Project Number U17N10941n. Report submitted to Glen Canyon National Recreation Area.

Butterfield, B., and E. Palmquist. 2023a. Evaluation of Impact of Streamflow Reduction Alternatives Under Consideration on Riparian Plant Communities and Vegetation Resources. Northern Arizona University and USGS Southwest Biological Science Center. February 8, 2023.

______. 2023b. Addendum to Riparian Resources Report: Predicted Impacts of Loss of HFEs under No Action. Northern Arizona University and USGS Southwest Biological Science Center. March 2, 2023.

California Water Boards. 2022. Status of Actions October 2022 PG&E Hinkley Chromium Contamination. Internet website: https://www.waterboards.ca.gov/lahontan/water_issues/projects/pge/docs/2022/PGE-Status-of-Actions-October-2022.pdf.

Central Arizona Project. 2023. Tribal Water Rights. Internet website: https://www.cap-az.com/about/tribal-water-rights/. Accessed February 2023.

Center for Disease Control (CDC). 2021. Climate Effects on Health: Regional Health Effects – Southwest. Internet website: https://www.cdc.gov/climateandhealth/effects/southwest.htm#print. Accessed February 2023.

Colorado River Basin Salinity Control Forum. 2020. Colorado River Salinity. Internet website: https://coloradoriversalinity.org/docs/2020%20REVIEW%20-%20Final%20w%20appendices.pdf.

Coulam, N. 2011. Hualapai Traditional Cultural Properties along the Colorado River, Coconino and Mohave Counties, Arizona, Registration Form, National Register of Historic Places.

Council on Environmental Quality (CEQ). 1997. Environmental Justice; Guidance under the National Environmental Policy Act. Internet website: https://www.epa.gov/environmentaljustice/ceq-environmental-justice-guidance-under-national-environmental-policy-act.

Cross W.F., Rosi-Marshall E.J., Behn K.E., Kennedy T.A. Hall Jr. R.O., Fuller A.E., and Baxter C.V. 2010. Invasion and production of New Zealand mud snails in the Colorado River, Glen Canyon. Biological Invasions 12:3033-3043.

Dale, L., and L. Dixon. 1998. The Impact of Water Supply Reductions on San Joaquin Valley Agriculture during the 1986–1992 Drought. Monograph report, Rand Corp., Santa Monica, CA. Internet website: https://www.rand.org/pubs/monograph_reports/MR552.html.

Deemer, B.R. 2023. Dissolved oxygen dynamics in Lake Powell and in the Glen Canyon tailwater-presentation for Annual Reporting Meeting, Bureau of Reclamation, Glen Canyon Dam Adaptive Management Program Meeting, January 24-25, 2023, Phoenix, AZ. Internet website: https://www.usbr.gov/uc/progact/amp/twg.html#twg2023.

Deemer, B. R., C. M. Andrews, K. E. Strock, N. Voichick, J. Hensleigh, J. R. Beaver, and R. Radtke. 2023. Over half a century record of limnology data from Lake Powell, desert southwest UNITED STATES: From reservoir filling to present day (1964–2021). Limnol Oceanogr Letters lol2.10310. doi:10.1002/lol2.10310.

Deemer, B.R., C.B. Yackulic, R.O. Hall, M.J. Dodrill, T.A. Kennedy, J.D. Muehlbauer, D.J. Topping, N. Voichick, and M.D. Yard. 2022. Experimental reductions in subdaily flow fluctuations increased gross primary productivity for 425 river kilometers downstream. *PNAS Nexus.* 1(3).

Deol, S., and B. Colby. 2018. Tribal economies: Water settlements, agriculture, and gaming in the western U.S. *Journal of Contemporary Water Research & Education* 163(1):45–63.

Department of the Interior (DOI). 2001. Record of Decision (ROD) for the Colorado River Interim Surplus Guidelines Final Environmental Impact Statement. January 2001. Internet website: https://www.usbr.gov/lc/region/g4000/surplus/surplus_rod_final.pdf

_____. 2007. Record of Decision (ROD) for the Colorado River Interim Guidelines for Lower Basin Shortages and the Coordinated Operations for Lake Powell and Lake Mead. December 2007. Internet website: https://www.usbr.gov/lc/region/programs/strategies/RecordofDecision.pdf.

_____. 2018. General Management Plan Amendment Low-Water Plan Environmental Assessment. National Park Service, US Department of the Interior, Washington, D.C.

_____. 2023a. Managing Indian Trust Assets. Internet website: https://www.doi.gov/ost/managing-indian-trust-assets#trustassets.

_____. 2023b. Interior Department Welcomes Significant Progress for Indian Water Rights Settlements. Internet website: https://www.doi.gov/pressreleases/interior-department-welcomes-significant-progress-indian-water-rights-settlements.

Dibble, D.L., C.B. Yackulic, T.A. Kennedy, K.R. Bestgen, and J.C. Schmidt. 2021. Water storage decisions will determine the distribution and persistence of imperiled river fishes. Ecological Applications. 31(2):e02279. doi 10.1002/eap.2279.

Dodrill, M. J., Yackulic, C. B., Gerig, B., Pine, W. E., Korman, J., & Finch, C. (2015). Do Management Actions to Restore Rare Habitat Benefit Native Fish Conservation? Distribution of Juvenile Native Fish Among Shoreline Habitats of the Colorado River. River Research and Applications, 31(10), 1203. Internet website: https://doi-org.libproxy.unm.edu/10.1002/rra.2842.

Dongoske, K. 2011. *Chimik'yana'kya dey'a* (Place of Emergence), *K'yawan' A: honanne* (Colorado River), and *Ku'nin A'l'akkew'a* (Grand Canyon), a Zuni Traditional Cultural Property, Nomination Form, National Register of Historic Places.

Drugova, T., K. Curtis, and M. Kim. 2020. Utah State University. Impacts of Drought on Tribal Economies in Arizona. Internet website: https://digitalcommons.usu.edu/cgi/ viewcontent.cgi?article=3177&context=extension_curall.

Duval, D., A. K. Bickel, and G. Frisvold. 2020. Arizona County Agricultural Economy Profiles. The University of Arizona. College of Agriculture and Life Sciences. Agriculture & Resource Economics. Internet website: .https://economics.arizona.edu/arizona-county-agricultural-economy-profiles.

East AE, Collins BD, Sankey JB, Corbett SC. 2016. Conditions and processes affecting sand resources at archeological sites in the Colorado River corridor below Glen Canyon Dam, Arizona. *U.S. Geological Survey Professional Paper 1825*. DOI: 10.3133/pp1825.

eFloras. 2023. Thelypteris puberula var. sonorensis. Flora of North America. Accessed January 2023.

Energy Information Administration (EIA). 2023. Energy Conversion Calculator. Internet website: https://www.eia.gov/energyexplained/units-and-calculators/energy-conversion-calculators.php.

Engel, E.C., S.R. Abella, and K.L. Chittick. Plant colonization and soil properties on newly exposed shoreline during drawdown of Lake Mead, Mojave Desert. 2014. Lake and Reservoir Management, 30:2, 105-114, DOI:10.1080/10402381.2013.878008.

Environmental Protection Agency (EPA). 2017. Climate Impacts on Society. Available at: https://19january2017snapshot.epa.gov/climate-impacts/climate-impacts-society_.html Accessed February 2023.

_____. 2022. GHG Emission Factors. Internet website: https://www.epa.gov/climateleadership/ghg-emission-factors-hub.

Fenneman, N.M. 1931. *Physiography of the Western United States*. New York and London: McGraw Hill, Book Company Inc.

Food and Agriculture Organization of the United Nations. 2023. Cultured Aquatic Species Information Programme. Text by Cowx, I.G. Fisheries and Aquaculture Division [online]. Rome. Internet website: https://www.fao.org/fishery/en/culturedspecies/oncorhynchus_mykiss/en.

Frisvold, G. B., L. E. Jackson, J. G. Pritchett, J. P. Ritten, and M. Svoboda. 2013. "Agriculture and ranching." In: *Assessment of Climate Change in the Southwest United States* (G. Garfin, A. Jardine, R. Merideth, M. Black, and S. LeRoy, Eds.). Island Press, Washington, D.C. Pp. 218–239.

Gaston, T., D. Harpman, J. Platt, and S. Piper, 2015, Recreation Economic Analysis for the Long-Term Experimental and Management Plan Environmental Impact Statement, Technical Report EC-2014-03, U.S. Bureau of Reclamation

Gilbert, Arizona. 2022. Water Supply Reduction Management Plan. Internet website: https://www.gilbertaz.gov/home/showpublisheddocument/41870/637643885794770000.

Glen Canyon Dam Adaptive Management Program. 2020. The Basin Fund. Internet website: http://gcdamp.com/index.php/The_Basin_Fund.

Graham, J.P. 2016. Glen Canyon National Recreation Area: Geological Resources Inventory Report. Natural Resources Report NPS/NRSS/GRD/NRR – 2016/1264. National Park Service. Fort Collins, Colorado. August.

Grams, P. E., J. C. Schmidt, and M. E. Andersen. 2010. 2008 High-Flow Experiment at Glen Canyon Dam—Morphologic Response of Eddy-Deposited Sandbars and Associated Aquatic Backwater Habitats along the Colorado River in Grand Canyon National Park. Open-File Report 2010-1032. US Geological Survey, Grand Canyon Monitoring and Research Center, Flagstaff, Arizona.

Grams, P. E., D. J. Topping, J. C. Schmidt, J. E. Hazel Jr., and M. Kaplinski. 2013. "Linking morphodynamic response with sediment mass balance on the Colorado River in Marble Canyon: Issues of scale, geomorphic setting, and sampling design." Journal of Geophysical Research: Earth Surface 118(2):361–381.

Grand Canyon Monitoring and Research Center (GCMRC). 2023. Discharge, Sediment and Water Quality, Grand Canyon Stations, Colorado River at Lees Ferry, AZ. Internet website: https://www.gcmrc.gov/discharge_qw_sediment/station/GCDAMP/09380000#.

Hannoun, D., and T. Tietjen. 2022. Lake Management under severe drought: Lake Mead, Nevada/Arizona. *Journal of American Water Resources Association.*

Hazel, Jr., J. E., M. A. Kaplinski, D. Hamill, D. Buscombe, E. R. Mueller, R. P. Ross, K. Kohl, and et al. 2022. "Multi-decadal sandbar response to flow management downstream from a large dam." In The Glen Canyon Dam on the Colorado River in Marble and Grand Canyons, Arizona. US Geological Survey Professional Paper 1873, US Geological Survey, Reston, Virginia.

Headwater Economics Economic Profile System. 2023. Socioeconomic Profiles for Study area counties. Internet website: https://headwaterseconomics.org/apps/economic-profile-system/.

Henderson, N. 2006. National Park Service, Salt Lake City, Utah. September through December 2006. Personal communications and email.

Holm, G., M. Terwilliger, B. Holton, and T. Kennedy. 2023. Wildlife in GRCA including Special Status Species. Unpublished Report. National Park Service.

Hopi CPO (Cultural Preservation Office). 2001. *Öngtupqa* (Grand Canyon), *Palavayu* (Little Colorado River), and *Pizizvayu* (Colorado River), A Hopi Traditional Cultural Property, Registration Form, National Register of Historic Places.

Hueftle, S. J. and L. E. Stevens. 2001. Experimental flood effects on the limnology of Lake Powell reservoir, Southwestern USA. Ecological Applications 11:13.

Imperial County. 2014. Agricultural crop and Livestock Report. Agricultural Commissioner Sealer of Weights and Measures. Internet website: https://agcom.imperialcounty.org/wp-content/uploads/2020/02/2014_Imperial_County_Crop_and_Livestock_Report.pdf.

______. 2015. Agricultural crop and Livestock Report. Agricultural Commissioner Sealer of Weights and Measures. Internet website: https://agcom.imperialcounty.org/wp-content/uploads/2020/02/2015_Imperial_County_Crop_and_Livestock_Report.pdf.

______. 2016. Agricultural crop and Livestock Report. Agricultural Commissioner Sealer of Weights and Measures. Internet website: https://agcom.imperialcounty.org/wp-content/uploads/2020/02/2016_Imperial_County_Crop_and_Livestock_Report.pdf.

______. 2017. Agricultural crop and Livestock Report. Agricultural Commissioner Sealer of Weights and Measures. Internet website: https://agcom.imperialcounty.org/wp-content/uploads/2020/02/2017_Imperial_County_Crop_and_Livestock_Report.pdf.

______. 2018. Agricultural crop and Livestock Report. Agricultural Commissioner Sealer of Weights and Measures. Internet website: https://agcom.imperialcounty.org/wp-content/uploads/2020/02/2018_Imperial_County_Crop_and_Livestock_Report.pdf.

IMPLAN. 2021. IMPLAN® model, 2021 data, using inputs provided by the user and IMPLAN Group LLC, IMPLAN System (data and software), 16905 Northcross Dr., Suite 120, Huntersville, NC 28078. Internet website: www.IMPLAN.com.

International Boundary and Water Commission. 2017. Minute Number 323: Extension of Cooperative Measures and Adoption of a Binational Water Scarcity Contingency Plan in the Colorado River Basin. United States and Mexico. September 21, 2017. Internet website: https://www.ibwc.gov/Files/Minutes/Min323.pdf.

______. 2019. Joint Report of the Principal Engineers with the Implementing Details of the Binational Water Scarcity Contingency Plan in the Colorado River Basin. United States and Mexico. July 11, 2019. Internet website: https://www.ibwc.gov/Files/joint_report_min323_bi_water_scarcity_contingency_plan_final.pdf.

______. 2021. Joint Report of the Principal Engineers with the Operational Provisions Applicable to Water for the Environment Stipulated in Minute 323. United States and Mexico. December 16, 2021. Internet website: https://www.ibwc.gov/Files/Min323_joint_report_eng.pdf.

James, T, A. Evans, E.E. Madly, and C. Kelly. 2014. The Economic Importance of the Colorado River to the Basin Region. W. P Carey School of Business, University of Arizona. December 18, 2014.

Joel, L. 2016. "The drought has created new gnarly rapids in the Grand Canyon." *Outside Magazine*. Internet website: https://www.outsideonline.com/outdoor-adventure/water-activities/drought-has-created-new-gnarly-rapids-grand-canyon/.

Johnson, M., L. Ratcliff, R. L. Shively, and L. Weiss. 2016. Looking Upstream: An Analysis of Low Water Levels in Lake Powell and the Impacts on Water Supply, Hydropower, Recreation, and the Environment: A Companion Report to The Bathtub Ring. Getches-Wilkinson Center for Natural Resources, Energy, & the Environment. University of Colorado Law School. Boulder, Colorado. Internet website: https://scholar.law.colorado.edu/cgi/viewcontent.cgi?httpsredir=1&article=1173&context=books_reports_studies.

Jones, D. K. and C. Root. 2021. Modified topobathymetric elevation data for Lake Powell. Utah Water Science Center. Data release. Internet website: https://doi.org/10.5066/P9H60YCF.

Kasprak, A., J. B. Sankey, J. Caster, and H. Fairley. 2023. Evaluation of Impacts of Streamflow Reduction Alternatives on Sand Exposure for Aeolian Landscape and Cultural Site Resources (Draft). US Geological Survey, Grand Canyon Monitoring and Research Center.

Kearney, M. S., B. H. Harris, B. Hershbein, E. Jacome, and G. Nantz. 2014. In time of Drought" Nine Economic Facts About Water in the United States. Brookings. October 20, 2014.

Kearsley, M. 2023. National Park Sevice, Grand Canyon, Arizona. Personal communications and email.

Kegerries, R.B., B.C. Albrecht, E.L. Gilbert, H. Brandenburg, A.L. Barkalow, M.C. McKinstry, H.E. Mohn, B.D. Healy, J.R. Stolberg, E.C. Omana Smith, C.B. Nelson, and R.J. Rogers. 2017. Occurrence and Reproduction by Razorback Sucker (*Xyrauchen texanus*) in the Grand Canyon, Arizona. The Southwestern Naturalist 62(3):227-232.

Kolbert, E. 2021. "The lost canyon under Lake Powell." *The New Yorker*. Internet website: https://www.newyorker.com/magazine/2021/08/16/the-lost-canyon-under-lake-powell.

Lahmers, T. and S. Eden. 2018, "Water and Irrigated Agriculture in Arizona." Arroyo, University of Arizona Water Resources Research Center, Tucson, AZ. Internet website: https://www.resolutionmineeis.us/sites/default/files/references/wrrc-2018.pdf.

Lower Colorado Multi-Species Conservation Program (LCR MSCP). 2022. Lower Colorado River Multi-Species Conservation Program Final Implementation Report, Fiscal Year 2023 Work Plan and Budget, Fiscal Year 2021 Accomplishment Report. Boulder City, Nevada.

Lukas, J. and E. Payton. 2020. Colorado River Basin Climate and Hydrology State of the Science. Western Water Assessment. Intern website: https://doi.org/10.25810/3hcv-w477.

Maldanado, R. P. 2011. Navajo Traditional Cultural Properties along the Colorado and Little Colorado Rivers in Coconino and Mohave Counties, Arizona, Registration Form, National Register of Historic Places.

Metropolitan Water District of Southern California (MWD). 2023. Drought Across The West. Internet website: https://www.mwdh2o.com/how-we-plan/drought/.

Mihalevich, B. A. 2022. "Advances in Process Understanding and Methods to Support River Temperature Modeling in Large Regulated Systems". All Graduate Theses and Dissertations. 8438. https://digitalcommons.usu.edu/etd/8438. .

Mihalevich, B. A., B.T. Neilson, C.A. Buahin, C.B. Yackulic, and J.C. Schmidt. Water Temperature Controls for Regulated Canyon-Bound Rivers. 2020. *Water Resources Research* 56(12).

Mortenson, S. G., P. J. Weisberg, and L. E. Stevens. 2012. The influence of floods and precipitation on *Tamarix* establishment in Grand Canyon, Arizona: Consequences for flow regime restoration, *Biol. Invasions*, 14(5), 1061– 1076.

Mueller, E. R. and P. E. Grams. 2021. "A Morphodynamic Model to Evaluate Long-Term Sandbar Rebuilding Using Controlled Floods in the Grand Canyon." *Geophysical Research Letters* 48(9):1–10.

National Oceanic and Atmospheric Administration. 2023. Climate at a Glance Regional Time Series. Retrieved from National Centers for Environmental Information. Internet website: https://www.ncei.noaa.gov/access/monitoring/climate-at-a-glance/regional/time-series.

National Park Service (NPS). 2006. Colorado River Management Plan. Grand Canyon National Park, Grand Canyon, Arizona.

______. 2010. Pearce Ferry Road Extension Announced. Internet website: https://www.nps.gov/lake/learn/news/pearce-ferry-road-extension-announced.htm.

______. 2016. Protect Feet and Paws from Sharp Quagga Mussel Shells on Lake Powell Shorelines. Internet website: https://www.nps.gov/glca/learn/news/protect-feet-and-paws-from-sharp-quagga-mussel-shells-on-lake-powell-shorelines.htm.

______. 2018. Glen Canyon National Recreation Area Socioeconomic Monitoring Pilot Implementation. Internet website: https://irma.nps.gov/DataStore/DownloadFile/627583. Accessed March 15, 2023.

______. 2019. Lake Powell Recreational Water Advisory – Glen Canyon NRA. Internet website: https://www.nps.gov/glca/learn/news/lpp.htm.

______. 2021. Immediate Access to Rainbow Bridge National Monument Impacted by Storm Debris and Low Lake Level. Internet website: https://www.nps.gov/glca/learn/news/20211020.htm.

______. 2022a. NPS Visitor Use Statistics Definitions. Internet website: https://www.nps.gov/subjects/socialscience/nps-visitor-use-statistics-definitions.htm.

______. 2022b. Naegleria Fowleri Fatality – Lake Mead NRA. Internet website: https://www.nps.gov/lake/learn/news/naegleria-fowleri-fatality.htm.

______. 2022c. 2021 National Park Visitor Spending Effects Economic Contributions to Local Communities, States, and the Nation. Natural Resource Report NPS/NRSS/EQD/NRR—2022/2395. Internet website: https://www.nps.gov/subjects/socialscience/vse.htm.

______.2022d. Glen Canyon National Recreation Area Annual Concessioner's Annual Financial Report 2022.

______. 2022e Glen Canyon National Recreation Area Annual Commercial Use Authorization Financial Report 2022.

______. 2023a. History of Total Annual Visits for Glen Canyon NRA. Internet website: https://irma.nps.gov/STATS/SSRSReports/Park%20Specific%20Reports/Annual%20Park%20Recreation%20Visitation%20(1904%20-%20Last%20Calendar%20Year)?Park=GLCA.

______. 2023b. Summary of Visitor Use by Month and Year (1976 – Last Calendar Year) for Glen Canyon NRA. Internet website: https://irma.nps.gov/STATS/SSRSReports/Park%20Specific%20Reports/Summary%20of%20Visitor%20Use%20By%20Month%20and%20Year%20(1979%20-%20Last%20Calendar%20Year)?Park=GLCA.

______. 2023c. Boating – Glen Canyon NRA. Internet website: https://www.nps.gov/glca/planyourvisit/boating.htm.

______. 2023d. Changing Lake Levels – Glen Canyon NRA. Internet website: https://www.nps.gov/glca/learn/changing-lake-levels.htm.

______. 2023e. History of Total Annual Visits for Grand Canyon National Park. Internet website: https://irma.nps.gov/Stats/SSRSReports/Park%20Specific%20Reports/Annual%20Park%20Recreation%20Visitation%20(1904%20-%20Last%20Calendar%20Year)?Park=GRCA. Accessed March 13, 2023.

______. 2023f. Summary of Visitor Use by Month and Year (Last Calendar Year) for Grand Canyon National Park. Internet website: https://irma.nps.gov/Stats/SSRSReports/Park%20Specific%20Reports/Summary%20of%20Visitor%20Use%20By%20Month%20and%20Year%20(1979%20-%20Last%20Calendar%20Year)?Park=GLCA. Accessed March 13, 2023.

______. 2023g. Lake Mead NRA Annual Park Recreation Visitation (1904 – Last Calendar Year). Internet website: https://irma.nps.gov/STATS/SSRSReports/Park%20Specific%20Reports/Annual%20Park%20Recreation%20Visitation%20(1904%20-%20Last%20Calendar%20Year)?Park=LAKE.

______. 2023h. Summary of Visitor Use by Month and Year (1979 – Last Calendar Year) for Lake Mead NRA. Internet website: https://irma.nps.gov/STATS/SSRSReports/Park%20Specific%20Reports/Summary%20of%20Visitor%20Use%20By%20Month%20and%20Year%20(1979%20-%20Last%20Calendar%20Year)?Park=LAKE.

______. 2023i. Mussel Update – Glen Canyon NRA. Internet website: https://www.nps.gov/glca/learn/nature/mussel-update.htm.

______. 2023j. Glen Canyon NRA Cultural, Paleontological, and Geologic Resources. Memorandum prepared by the NPS and submitted to the Bureau of Reclamation.

______. 2023k. Updated Affected Environment Information – Cultural Resources – Lake Mead. Memorandum prepared by the NPS and submitted to the Bureau of Reclamation.

______. 2023l. Vegetation/Grazing Effects on Lake Powell, Glen Canyon National Recreation Area; qualitative analysis for the 2007 Guidelines SEIS considers No action vs. DOI alternative as proposed in the cooperator call on Jan 26, 2023.

______. 2023m. NPS summary of resource topic affected by Reclamation SEIS – Air Quality. analysis for the 2007 Guidelines SEIS considers No action vs. DOI alternative as proposed in the cooperator call on Jan 26, 2023.

National Weather Service GIS (National Weather Service Geographic Information Systems). 2023. Rivers. Internet website: https://www.weather.gov/gis/Rivers.

NatureServe. 2023. NatureServe Network Biodiversity Location Data accessed through NatureServe Explorer [web application]. NatureServe, Arlington, Virginia. Internet website: https://explorer.natureserve.org/. Accessed February 2023.

Northern Arizona University. 2022a. Lake Havasu State Park: Visitation Counts. Arizona Hospitality Research & Resource Center, School of Hotel & Restaurant Management. Flagstaff, Arizona.

______. 2022b. Cattail Cove State Park: Visitation Counts. Arizona Hospitality Research & Resource Center, School of Hotel & Restaurant Management. Flagstaff, Arizona.

______. 2023. Northern Mexican Gartersnake Thamnophis eques megalops. Gartersnake Research Project. Northern Arizona University.

Palmquist, E.C., B.E. Ralston, D.M. Merritt, and P.B. Shafroth. 2018. Landscape-scale processes influence riparian plant composition along a regulated river. Journal of Arid Environments 148 (2018) 54-64.

Paukert, C. P., and R. S. Rogers. 2004. Factors affecting condition of flannelmouth sucker in the Colorado River, Grand Canyon, Arizona. North American Journal of Fisheries Management 24:648-653.

Pedersen, K. 2023. Email from Kerri Pedersen to Matt Westover pertaining to northern leopard frog occurrence and impacts. March 17, 2023.

Peterson, B. 2022. "On the Colorado River, growing concern for trout and chub". The Associated Press. Internet website: https://www.cpr.org/2022/09/19/colorado-river-trout-chub-populations-drop/.

Riverside County. 2014. Agricultural production Report. Riverside County Agricultural Commissioner's Office. Internet website: https://rivcoawm.org/sites/g/files/aldnop221/files/migrated/Portals-0-Publications-Crop-Reports-EntireCounty-2014-Riverside-County-Agricultural-Production-Report.pdf.

_____. 2015. Agricultural production Report. Riverside County Agricultural Commissioner's Office. Internet website: https://rivcoawm.org/sites/g/files/aldnop221/files/migrated/Portals-0-Publications-2015-Reports-2015-Riverside-County-Agricultural-Production-Report.pdf.

_____. 2016. Agricultural production Report. Riverside County Agricultural Commissioner's Office. Internet website: https://rivcoawm.org/sites/g/files/aldnop221/files/migrated/Portals-0-Publications-Crop-Reports-EntireCounty-2016-crop-report.pdf.

_____. 2017. Agricultural production Report. Riverside County Agricultural Commissioner's Office. Internet website: https://rivcoawm.org/sites/g/files/aldnop221/files/migrated/Portals-0-PDF-2017-crop-report.pdf.

Rogowski, D. L. and J. K. Boyer. 2020. Status of the Lees Ferry Rainbow Trout Fishery: 2019 Annual Report. Arizona Game and Fish Department, Colorado River Research Office. Submitted to the Grand Canyon Monitoring and Research Center, Flagstaff, Arizona.

Rogowski, D.L., R.J. Osterhoudt, E.M. Harrison, and J.K. Boyer. 2018. Humpback Chub (Gila cypha) range expansion in the western Grand Canyon. Western North American Naturalist 78(1): 26–38.

Salter, G. and P. E. Grams. 2023. Evaluation of Effects of Streamflow Reduction Alternatives under Consideration on Sediment Resources. US Geological Survey, Grand Canyon Monitoring and Research Center, Flagstaff, Arizona.

San Bernardino County. 2014. Annual Crop Report. Agriculture/Weights and Measures. Community Services Group. Internet website: https://awm.sbcounty.gov/wp-content/uploads/sites/84/2022/04/2014CropReport.pdf.

_____. 2015. Annual Crop Report. Agriculture/Weights and Measures. Community Services Group. Internet website: https://awm.sbcounty.gov/wp-content/uploads/sites/84/2022/04/2015CropReport.pdf.

______. 2016. Annual Crop Report. Agriculture/Weights and Measures. Community Services Group. Internet website: https://awm.sbcounty.gov/wp-content/uploads/sites/84/2022/04/2016CropReport.pdf.

______. 2017. Annual Crop Report. Agriculture/Weights and Measures. Community Services Group. Internet website: https://awm.sbcounty.gov/wp-content/uploads/sites/84/2022/04/2017CropReport.pdf.

______. 2018. Annual Crop Report. Agriculture/Weights and Measures. Community Services Group. Internet website: https://awm.sbcounty.gov/wp-content/uploads/sites/84/2022/04/2018CropReport.pdf.

Sankey, J. B., J. Caster, A. Kasprak, and H. Fairley. 2022. "The influence of drying on the aeolian transport of river-sourced sand". *Journal of Geophysical Research: Earth Surface* 127(12):e2022JF006816.

Santucci, V.L. and J.S. Tweet, editors. 2021. Grand Canyon National Park Centennial Paleontological Resources Inventory —A Century of Fossil Discovery and Research: Utah Geological Association.

Smith, J. 2022. Upper Colorado River Endangered Fish Recovery Program. 2022 Annual Report. Utah Division of Wildlife Resources.

Southern Nevada Water Association. 2021. Water Resources Plan. Internet website: 2023 Water Resource Plan (snwa.com).

Southern Nevada Water Authority (SNWA). 2023. SEIS data from SNWA for Lake Mead and Lake Mohave.

Tillman, F.D., A.L. Coes, D.W. Anning, J.P. Mason, and T.B. Coplen. 2019. Investigation of recent decadal-scale cyclical fluctuations in salinity in the lower Colorado River. *Journal of Environmental Management, 235(2019), 442-452.*

United States Global Change Research Program. 2018. Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II: [Reidmiller, D. R., C. W. Avery, D. R. Easterling, K. E. Kunkel, K. L. M. Lewis, T. K. Maycock, and B. C. Stewart (eds.)]. US Global Change Research Program, Washington, D.C. Pp. 1515. Internet website: https://nca2018.globalchange.gov/downloads/NCA4_2018_FullReport.pdf.

University of Arizona. 2001. Historic Crop and Livestock Budgets. College of Agricultural & Live Sciences. Agricultural & Resource Economics. Internet website: https://economics.arizona.edu/historic-crop-and-livestock-budgets.

University of California Davis. 2023. Archived studies in the southeast interior region. Agricultural and resource economics. University of California, Davis. Internet website: https://coststudies.ucdavis.edu/en/archived/region/southeast-interior/.

US Bureau of Labor Statistics. 2023. Internet website: https://www.bls.gov/data/inflation_calculator.htm.

US Census Bureau. 2021a. 2017–2021 American Community Survey 5-Year Estimates: Table DP05. Internet website: https://data.census.gov/table?text=DP05&g=0400000US04,06,32,49_0500000US04001,04005,04007,04009,04012,04013,04015,04017,04019,04021,04027,06025,06037,06059,06065,06071,06073,32003,49017,49025,49037&tid=ACSDP5Y2021.DP05&moe=false.

______. 2021b. 2017–2021 American Community Survey 5-Year Estimates: Table B03002. Internet website: https://data.census.gov/table?text=B02010&g=0400000US04,06,32,49_0500000US04001,04005,04007,04009,04012,04013,04015,04017,04019,04021,04027,06025,06037,06059,06065,06071,06073,32003,49017,49025,49037&tid=ACSDT5Y2021.B02010&moe=false.

______. 2021c. 2017–2021 American Community Survey 5-Year Estimates: Table S1701. Internet website: https://data.census.gov/table?text=S1701&g=0400000US04,06,32,49_0500000US04001,04005,04007,04009,04012,04013,04015,04017,04019,04021,04027,06025,06037,06059,06065,06071,06073,32003,49017,49025,49037&tid=ACSST5Y2021.S1701&moe=false.

US Census Bureau GIS (US Census Bureau Geographic Information Systems). 2021. American Indian, Alaska Native Areas, Hawaiian Home Lands (national). Internet website: https://www.census.gov/geographies/mapping-files/time-series/geo/cartographic-boundary.html.

US Census Bureau GIS (US Census Bureau Geographic Information Systems). 2023. US Counties. Internet website: https://www.census.gov/cgi-bin/geo/shapefiles/index.php.

US Department of Agriculture. 2019a. 2017 Census of Agriculture. Arizona. State and County Data. Volume 1. Geographic Area Series. Part 3. AC-17-A-3. Issued April 2019. Internet website: https://www.nass.usda.gov/Publications/AgCensus/2017/Full_Report/_Volume_1,_Chapter_2_County_Level/Arizona/azv1.pdf.

______. 2019b. 2017 Census of Agriculture. California. State and County Data. Volume 1. Geographic Area Series. Part 5. AC-17-A-5. Issued April 2019. Internet website: https://www.nass.usda.gov/Publications/AgCensus/2017/Full_Report/Volume_1,_Chapter_2_County_Level/California/cav1.pdf.

______. 2019c. 2017 Census of Agriculture. Nevada. State and County Data. Volume 1. Geographic Area Series. Part 28. AC-17-A-28. Issued April 2019. Internet website: https://www.nass.usda.gov/Publications/AgCensus/2017/Full_Report/Volume_1,_Chapter_2_County_Level/Nevada/nvv1.pdf.

US Fish and Wildlife Service (Service). 2018a. Species status assessment report for the razorback sucker Xyrauchen texanus. US Fish and Wildlife Service, Mountain-Prairie Region (6), Denver, Colorado.

______. 2018b. Species status assessment for the Humpback Chub (Gila cypha). US Fish and Wildlife Service, Mountain-Prairie Region (6), Denver, Colorado.

______. 2022. Species status assessment report for the Colorado pikeminnow (Ptychocheilus lucius). Mountain-Prairie Region, Denver, Colorado. Version 1.1.

US Geological Survey (USGS). 2011. Effects of Three High-flow Experiments on the Colorado River Ecosystem Downstream from GCD, Arizona, US Geological Survey Circular 1366. Internet website: https://pubs.usgs.gov/circ/1366/.

______. 2012. A synthesis of Aquatic Science for Management of Lakes Mead and Mohave. Internet website: https://pubs.usgs.gov/circ/1381/pdf/circ1381.pdf#page=62.

______. 2015. Irrigation, Crop. Water Use Data for Arizona. La Paz, Maricopa, Mohave, Pima, Pinal, and Yuma Counties. Refresh Date: June 2018. Internet website: https://waterdata.usgs.gov/az/nwis/water_use?format=html_table&rdb_compression=file&wu_area=County&wu_year=2015&wu_county=012%2C013%2C015%2C019%2C021%2C027&wu_category=IC&wu_county_nms=La%2BPaz%2BCounty%252CMaricopa%2BCounty%252CMohave%2BCounty%252CPima%2BCounty%252CPinal%2BCounty%252CYuma%2BCounty&wu_category_nms=Irrigation%252C%2BCrop.

______. 2016. Water Clarity of the Colorado River—Implications for Food Webs and Fish Communities. US Geological Survey Fact Sheet 2016–3053. Internet website: https://pubs.er.usgs.gov/publication/fs20163053.

______. 2018. High-Flow Experiments on the Colorado River. Southwest Biological Science Center. Internet website: https://www.usgs.gov/centers/southwest-biological-science-center/science/high-flow-experiments-colorado-river.

______. 2021. Large Decreases in Upper Colorado River Salinity Since 1929. Long-term Data to Help Protect Water Quality for US and Mexico. Internet website: https://www.usgs.gov/news/state-news-release/large-decreases-upper-colorado-river-salinity-1929.

______. 2022. Sediment Transport in the Colorado River and All-American Canal system at Imperial Dam. Internet website: https://www.usgs.gov/centers/arizona-water-science-center/science/sediment-transport-colorado-river-and-all-american.

______. 2023a. Lake Powell CE-QUAL-W2 water quality modeling for SEIS.

______. 2023b. Dissolved Oxygen Modeling Description 20230306.

______. 2023c. Colorado River Near Grand Canyon, AZ Gauge 09402500. Retrieved from USGS Water Data. Internet website: https://waterdata.usgs.gov/monitoring-location/09402500/#parameterCode=00065&timeSeriesId=6291&period=P7D (last visited March 17, 2023).

______. 2023d. FY22 Glen Canyon Dam Adaptive Management Program Technical Working Group Annual Reporting Meeting Proceedings. Internet website: https://www.usbr.gov/uc/progact/amp/twg/2023-01-26-twg-meeting/20230126-AnnualReportingMeeting-ProceedingsFY2022AnnualReportingMeeting-508-UCRO.pdf.

______. 2023e. Proceedings of the Fiscal Year 2022 Annual Reporting Meeting to the Glen Canyon Dam Adaptive Management Program. Southwest Biological Science Center Grand Canyon Monitoring and Research Center. U. Department of the Interior. USGS. Flagstaff, Arizona.

US Geological Survey NHD GIS (US Geological Survey National Hydrography Dataset Geographic Information Systems). 2023. National Hydrography Dataset Best Resolution (NHD) – Arizona, California, Colorado, Nevada, New Mexico, Utah, and Wyoming. Internet website: https://prd-tnm.s3.amazonaws.com/index.html?prefix=StagedProducts/Hydrography/NHD/State/GDB/.

US Global Change Research Program (USGCRP). 2018. Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II: [Reidmiller, D. R., C. W. Avery, D. R. Easterling, K. E. Kunkel, K. L. M. Lewis, T. K. Maycock, and B. C. Stewart (eds.)]. US Global Change Research Program, Washington, DC. Pp. 1515. Internet website: https://nca2018.globalchange.gov/downloads/NCA4_2018_FullReport.pdf.

Utah Department of Natural Resources. 2006. Conservation and management plan for three fish species in Utah. Publication Number 06-17.

______. 2021. Lake Powell Fisheries Investigations Completion Report. May 2015–April 2020.

Valdez, R., and R. Ryel. 1995. Life history and ecology of the humpback chub (*Gila cypha*) in the Colorado River, Grand Canyon, Arizona, Final report. Bureau of Reclamation. Upper Colorado Region, and Glen Canyon Environmental Studies. Bio/West, Inc, Logan, UT.

Valdez, R.A. and S.W. Carothers. 1998. The aquatic ecosystem of the Colorado River in Grand Canyon. Final Report of SWCA, inc., Flagstaff, Arizona, to US Bureau of Reclamation, Upper Colorado Region.

Valdez, R.A., D.A. House, M.A. McLeod, and S.W. Carothers. 2012. Review and summary of razorback sucker habitat in the Colorado River system, Report Number 1. Final Report prepared by SWCA, Environmental Consultants for US Bureau of Reclamation, Upper Colorado Region, Salt Lake City, Utah.

Valdez, R.A., D.W. Speas, and D.M. Kubly. 2015. Benefits and risks of temperature modification at Glen Canyon Dam to fishes of the Colorado River through the Grand Canyon. US Bureau of Reclamation, Upper Colorado Region, Salt Lake City, Utah.

Vanhaverbeke, R., D.M. Stone, M.J. Dodrill, K.L. Young, and M.J. Pillow. 2017. Population Expansion of Humpback Chub in Western Grand Canyon and Hypothesized Mechanisms. The Southwestern Naturalist 62(4):285-292.

Vernieu, W. S. 2010. Effects of the 2008 High-Flow Experiment on Water Quality in Lake Powell and Glen Canyon Dam Releases, Utah-Arizona. Open-File Report 2010–1159. 2010–1159 US Geological Survey.

Voichick, N., and D.J. Topping. 2010. Comparison of Turbidity to Multi-Frequency Sideways-Looking Acoustic-Doppler Data and Suspended-Sediment Data in the Colorado River in Grand Canyon, 2nd Joint Federal Interagency Conference, Las Vegas, Nevada, June 27–July 1.

Walters, D.M., E. Rosi-Marshall, T.A. Kennedy, W.F. Cross, and C.V.Baxter. 2015. Mercury and selenium accumulation in the Colorado River food web, Grand Canyon, USA. *Environmental Toxicology and Chemistry.* 34(10):2385-2394.

Wang, J. and J. Schmidt. 2020. Stream flow and Losses of the Colorado River in the Southern Colorado Plateau. Internet website: https://qcnr.usu.edu/coloradoriver/files/news/FS-White-Paper-5.pdf.

Ward D.L., R. Morton-Starner, and B. Vaage. 2016. Effects of turbidity on predation vulnerability of juvenile humpback chub to rainbow and brown trout. Journal of Fish and Wildlife Management 7(1):205-212.

Warziniack, T. and T. C Brown. 2019. Environ. Res. Lett. 14 084036. Internet website: https://iopscience.iop.org/article/10.1088/1748-9326/ab2b76.

Welsh, S. L., N. D. Atwood, S. Goodrich, and L. C. Higgins, editors. 1987. A Utah Flora. Great Basin Naturalist Memoirs No. 9. Brigham Young University, Provo.

Western Area Power Administration (WAPA). 2023. GTMax modeling results.

Western Electricity Coordinating Council (WECC). 2023. State of the Interconnection. Capacity. Internet website: https://www.wecc.org/epubs/StateOfTheInterconnection/Pages/Capacity.aspx.

Williams, N. T. 2007. Modeling dissolved oxygen in Lake Powell using CE-QUAL-W2. Civil and Environmental Engineering M.S. Thesis, Brigham Young University, Provo UT., 120.

Wright, S. A., D. J. Topping, D. M. Rubin, and T. S. Melis. 2010. "An approach for modeling sediment budgets in supply-limited rivers." *Water Resources Research* 46(10):1–18.

Yackulic, C. 2023. Updated smallmouth bass write-up. Preliminary report. Grand Canyon Monitoring and Research Center, Flagstaff, AZ.

Yang, J., H. Lv, J. Yang, L. Liu, X. Yu, and H. Chen. 2016. Decline in water level boosts cyanobacteria dominance in subtropical reservoirs. *Science of the Total Environment*. 557-558:445-452.

Zhang, Q. and R.M. Hirsch. 2019. River Water-Quality Concentration and Flux Estimation Can be Improved by Accounting for Serial Correlation Through an Autoregressive Model. *Water Resources Research*. 55(11):9705-9723.

This page intentionally left blank.

Glossary

acre-foot (af)—Volume of water (43,560 cubic feet) that would cover 1 acre to a depth of 1 foot.

adaptive management—A method for examining alternative strategies for meeting measurable biological goals and objectives, and then, if necessary, adjusting future conservation management actions according to what is learned.

affected environment—Existing biological, physical, social, and economic conditions of an area that are subject to change, both directly and indirectly, as the result of a proposed human action.

algae—Simple plants containing chlorophyll; most live submerged in water.

allocation, allotment—Refers to a distribution of water through which specific persons or legal entities are assigned individual rights to consume pro rata shares of a specific quantity of water under legal entitlements. For example, a specific quantity of Colorado River water is distributed for use within each Lower Division State through an apportionment. Water available for consumptive use in that state is further distributed among water users in that state through the allocation. An allocation does not establish an entitlement; the entitlement is normally established by a written contract with the United States government. *See also* Lower Division States.

alluvium—Sedimentary material transported and deposited by the action of flowing water.

ambient—Surrounding natural conditions (or environment) in a given place and time.

amphibian—Vertebrate animal that has a life stage in water and a life stage on land (for example, salamanders, frogs, and toads).

annual flow-weighted average concentration—A weighted average of monthly total dissolved solids (TDS) concentrations for a year, where the weight for each month is based on the relative flow for each month.

Annual Operating Plan for Colorado River Reservoirs (AOP)—The AOP describes how Reclamation will manage Colorado River resources over a 12-month period, consistent with the Long-Range Operating Criteria and the *Arizona v. California* 1964 Supreme Court Decree. The AOP is prepared annually by Reclamation in cooperation with the Basin States, Mexico, appropriate federal agencies, Indian Tribes, state and local agencies, and the general public, including governmental interests, as required by federal law. As part of the AOP process, the Secretary of the Department of the Interior (Secretary) makes annual determinations regarding the availability of Colorado River water for deliveries to the Lower Division States of the Colorado River Basin. *See also* Lower Division States.

apportionment—Refers to the distribution of water available to each Lower Division State in Normal, Surplus or Shortage condition years, as set forth, respectively, in Articles II(B)(1), II(B)(2), and II(B)(3) of the 1964 Supreme Court Decree in the case of *Arizona v. California*.

appropriative rights—The right to divert a specified quantity of water at a specified point of diversion for reasonable and beneficial uses at a specified place of use for a specified manner of use. Appropriative rights are generally "first-in-time, first-in-right"(that is, one appropriative right has priority over appropriative rights established later).

backwater—A relatively small, generally shallow area of a river with little or no current.

banked groundwater—Water that has been stored temporarily in a groundwater aquifer. Banked groundwater can be recovered for use at a later time.

base load—Minimum load in a power system over a given period of time.

Basin States—In accordance with the Colorado River Compact of 1922, the Colorado River Basin within the United States consists of those parts of Arizona, California, Colorado, Nevada, New Mexico, Utah, and Wyoming within and from which waters drain naturally into the Colorado River. These seven states are referred to as the Basin States. *See also* Colorado River Compact of 1922.

biological assessment (BA)—To facilitate compliance with Section 7(a)(2) of the Endangered Species Act (ESA), federal agencies must prepare a BA pursuant to Section 7(c)(1) of the ESA that identifies the likely effects of the proposed federal action on threatened and endangered species. *See also* Endangered Species Act.

biological opinion (BO)—Document stating the United States Fish and Wildlife Service (Service) and/or the National Marine Fisheries Service opinion as to whether a federal action is likely to jeopardize the continued existence of a threatened or endangered species or result in the destruction or adverse modification of critical habitat.

bypass flows—Saline agricultural return flows from the Wellton-Mohawk Irrigation and Drainage District that are routed to the Cienega de Santa Clara in Mexico to ensure compliance with the salinity provisions of Minute 242 of the 1944 Water Treaty.

bypass tubes—Another term for river outlet works.

candidate species—Plant or animal species not yet officially listed as threatened or endangered under the ESA, but which is undergoing status review by the Service.

capacity—The maximum amount of energy that can be instantaneously produced.

catch—At a recreational fishery, refers to the number of fish captured, whether they are kept or released.

channel (watercourse)—An open conduit either naturally or artificially created that periodically or continuously contains moving water, or that forms a connecting link between two bodies of water.

Some terms used to describe natural channels are river, creek, run, branch, and tributary. Natural channels may be single or braided. Two terms used to describe artificial channels are canal and floodway.

Cladophora—Filamentous green alga important to the food chain in the Colorado River downstream of Glen Canyon Dam.

Colorado River Basin (Basin)—The drainage area of the Colorado River system. The Basin occupies an area of approximately 250,000 square miles in the southwestern United States and 3,500 square miles in northwestern Mexico. The Colorado River Compact of 1922 divided the Colorado River system into two subbasins: the Upper Basin and the Lower Basin. It also divided the seven states within the Basin into the Upper Division and the Lower Division. Upper Division States include Colorado, New Mexico, Utah, and Wyoming; the Lower Division States include Arizona, California, and Nevada. Additionally, 30 federally recognized Tribes are in the Basin.

Colorado River Basin Project Act of 1968 (CRBPA)—This act authorized construction of a number of water development projects, including the Central Arizona Project (CAP), and required the Secretary to develop the Criteria for Coordinated Long-Range Operation of Colorado River Reservoirs, or Long-Range Operating Criteria (LROC).

Colorado River Basin Salinity Control Forum—The organization dedicated to controlling Colorado River salinity; it consists of representatives of the seven Basin States.

Colorado River Compact of 1922—The agreement concerning the apportionment of the use of the waters of the Colorado River Basin, dated November 24, 1922, executed by commissioners for Arizona, California, Colorado, Nevada, New Mexico, Utah, and Wyoming. It was approved by Herbert Hoover, representative of the United States, and proclaimed effective by the president of the United States on June 25, 1929.

Colorado River Simulation System (CRSS)—An operational model of the Colorado River Basin based on a monthly time step.

Colorado River system—The portion of the Colorado River and its tributaries within the United States as defined in the Colorado River Compact of 1922.

compact—The Colorado River Compact of 1922.

compact point—The reference point designated by the Colorado River Compact of 1922 as dividing the Colorado River Basin into two subbasins, the Upper Basin and the Lower Basin. The compact point is Lee Ferry, Arizona. *See also* Lee Ferry Compact Point.

conductivity—A measure of water's ability to pass an electrical current.

Consolidated Decree—Entered by the United States Supreme Court on March 27, 2006, in the case of *Arizona v. California,* 547 US 150 (2006). In 1963, the Supreme Court reached a decision in the case of *Arizona v. California.* The 1964 Supreme Court decree in the case of *Arizona v. California* implemented the 1963 Decision. This 1964 Supreme Court decree was supplemented over time after its adoption, and the Supreme Court entered a Consolidated Decree in 2006 that incorporates all applicable provisions of the earlier-issued decisions and decrees.

consumptive use—For purposes of this supplemental environmental impact statement (SEIS), diversions of water from mainstream Colorado River, including water withdrawn from the mainstream through underground pumping, minus any measured and unmeasured return flows.

contractors—Those who hold entitlements to Colorado River water. Contractors consist of the federal government, states, Indian Tribes, and various public and private entities that are recognized under the Consolidated Decree, hold a Section 5 Contract with the Secretary, or have a Secretarial Reservation of water. *See also* Consolidated Decree.

conveyance loss—Water that is lost in transit from a pipe, canal, conduit, or ditch by leakage or evaporation. If the water is lost due to leakage, it may be considered return flow if it percolates to an aquifer and is available for reuse. If the water evaporates, it is considered consumptive use.

cooperating agency—With respect to the National Environmental Policy Act of 1969, as amended (NEPA) process, an agency that has jurisdiction by law or special expertise concerning an aspect of a proposed federal action, and that is requested by the lead agency to participate in the preparation of an environmental impact statement (EIS).

covered species—Those species addressed in the Lower Colorado River Multi-Species Conservation Program (LCR MSCP) for which conservation measures would be implemented and for which authorization for "take" is being requested under Section 10 of the ESA. *See also* take.

criteria—Standards used for making a determination.

critical habitat—Specific areas with physical or biological features essential to the conservation of a listed species and that may require special management considerations or protection. These areas have been legally designated via *Federal Register* notices.

cubic foot per second (cfs)—A measure of water flow equal to 1 cubic foot of water passing a point on the stream in 1 second of time.

cultural resource—Building, site, district, structure, or object significant in history, architecture, archaeology, culture, or science.

dead pool—Elevation at which water cannot be regularly released from a reservoir, which would effectively preclude Colorado River diversions to downstream users.

dead storage—Reservoir space from which stored water cannot be evacuated by gravity.

delta sediment—deposit formed at the mouth of the Colorado River and other rivers where they enter Lake Powell, Lake Mead, or the Gulf of California.

depletion—Loss of water from a stream, river, or basin resulting from consumptive use.

deposition—Settlement of material out of the water column and on to the streambed. Occurs when the energy of flowing water is unable to support the load of suspended sediment.

discharge (flow)—Volume of water that passes a given point within a given period of time; expressed in this SEIS in cubic feet per second (cfs). *See also* cubic foot per second.

dissolved oxygen (DO)—Amount of free oxygen found in water; perhaps the most commonly employed measurement of water quality. Low DO levels adversely affect fish and other aquatic life. The ideal dissolved oxygen for fish life is between 7 milligrams per liter (mg/L) and 9 mg/L; most fish cannot survive when DO falls below 3 mg/L.

diversion(s)—Colorado River water withdrawn from the mainstream, including water diverted from reservoirs or drawn from the mainstream by underground pumping.

domestic use—Refers to the use of water for household, stock, municipal, mining, milling, industrial, and other like purposes; excludes the generation of electrical power.

draw down—Lowering of a reservoir's elevation; process of depleting a reservoir or groundwater storage.

ecosystem—Complex system composed of a community of fauna and flora and that system's chemical and physical environments.

electric power system—Physically connected electric-generating, transmission, and distribution facilities operated as a unit under one control.

electrical demand—Energy requirement placed upon a utility's generation at a given instant or averaged over any designated period of time.

endangered species—A species or subspecies whose survival is in danger of extinction throughout all or a significant portion of its range.

Endangered Species Act (ESA)—The Endangered Species Act (ESA) of 1973 (16 USC 1531–1544), as amended; under Section 9, it provides for the prohibition of "take" of any fish or wildlife species listed as threatened or endangered under the ESA unless specifically authorized by regulation. *See also* take.

energy—What is produced by powerplants; measured in kilowatt hours.

entitlement—Refers to an authorization to beneficially consume Colorado River water pursuant to a decreed right; a contract with the United States through the Secretary or a Secretarial Reservation of water.

epilimnion—Thermal layering of water in lakes and streams. *See also* stratification.

firm energy or power—Non-interruptible energy or power guaranteed by the supplier to be available at all times except for reasons of uncontrollable forces or "continuity of service" contract provisions.

flood—An overflow or inundation that comes from a river or other body of water, and causes or threatens damage. Any relatively high streamflow overtopping the natural or artificial banks in any reach of a river or stream. A relatively high flow as measured by either gage height or discharge quantity.

flood control pool—Reservoir volume above the active conservation and joint-use pool that is reserved for flood runoff and then evacuated as soon as possible to keep that space ready for the next flood.

flood control release—The release of water from Lake Mead and the operation of Hoover Dam for flood control purposes pursuant to the reservoir operating criteria specified in the February 8, 1984, Field Working Agreement between the United States Army Corps of Engineers (USACE) and the Bureau of Reclamation (Reclamation), and the USACE regulations contained in 33 Code of Federal Regulations (CFR) 208.11.

flow—Volume of water passing a given point per unit of time expressed in cubic foot per second. *See also* cubic foot per second.

forage fish—Generally, small fish that reproduce prolifically and are consumed by predators.

fore bay—Impoundment immediately above a dam or hydroelectric plant intake structure. The term is applicable to all types of hydroelectric developments (storage, run-of-river, and pumped storage).

fry—Life stage of fish between the egg and fingerling stages.

full pool—Volume of water in a reservoir at maximum design elevation.

gaging station—Specific location on a stream where systematic observations of hydrologic data are obtained through mechanical or electrical means.

gigawatt-hour (GWh)—One billion watt-hours of electrical energy.

headwater—The source and upper part of a stream.

historic property—Any district, site, building, structure, or object listed on or eligible for listing on the National Register of Historic Places (36 CFR 800.16(l)(1)).

hydropower—The use of water to produce electricity.

hypolimnetic zone—The deep portion of a lake or reservoir volume generally classified as below the level of the thermocline.

hypolimnion—Thermal layering of water in lakes and streams; the lower stratum of the water column of a reservoir. This layer is generally undisturbed, and respiration and decomposition predominate. *Also see* stratification.

important farmlands—Prime farmland, unique farmland, farmland of statewide importance, and farmland of local importance, as defined by the United States Department of Agriculture Natural Resources Conservation Service (formerly the Soil Conservation Service). The categorization of farmland is based on a soil classification system that accounts for the physical and chemical characteristics of the land and the suitability of the land for producing crops. Important farmlands are afforded special protection due to their importance to agricultural production.

impoundment—Body of water created by a dam.

in situ—In archaeology, and as used in this SEIS, an artifact that has not been moved from its original place of deposit.

incidental take—Defined under the ESA as take that is "incidental to, and not the purpose of, the carrying out of an otherwise lawful activity" (50 CFR 17.22 and 17.32). *See also* take.

Indian trust assets (ITAs)—"legal interests" in "assets" held in "trust" by the federal government for federally recognized Indian Tribes or individual Indians.

inflow—Water flowing into a lake or reservoir from a river and/or its tributaries, or water entering a river from tributaries.

irrigated area—The gross farm area upon which water is artificially applied for the production of crops, with no reduction for access roads, canals, or farm buildings.

irrigation—The controlled application of water to arable lands to supply water requirements not satisfied by rainfall.

juvenile—Young fish older than 1 year but not having reached reproductive age.

kilowatt-hour (kWh)—One thousand watt-hours of electrical energy.

land cover type—A classification system to describe vegetation and other habitat types (such as cottonwood willow, honey mesquite, and marsh).

landscape character—Overall visual appearance of a given landscape based on the form, line, color, and texture associated with the landscape's vegetation, landforms/water, and human-made modifications. These factors give the area a distinctive quality that distinguishes it from its immediate surroundings.

Las Vegas Valley—The topographic basin containing the city of Las Vegas, the city of North Las Vegas, the city of Henderson, and certain unincorporated townships of Clark County.

Las Vegas Wash—The natural drainage channel for the entire Las Vegas Valley. It is dominated by wastewater flows from the city of Las Vegas, Clark County Sanitation District, and city of Henderson wastewater treatment plants. It terminates in the Las Vegas Bay of Lake Mead.

Law of the River—As applied to the Colorado River, a body of documents the Secretary uses to carry out the responsibility to manage the mainstream waters of the Lower Basin pursuant to applicable federal law. The Secretary is vested with this responsibility. This collective set of documents comprising numerous operating criteria, regulations, and administrative decisions included in federal and state statues, interstate compacts, court decisions and decrees, an international treaty, and contracts with the Secretary apportions the Colorado River waters and regulates the use and management of the Colorado River among the seven Basin States and Mexico.

lead agency—An agency initiating and overseeing the preparation of an EIS. For this SEIS, Reclamation is the lead agency for compliance with NEPA.

Lee Ferry Compact Point—Identified the reference point that marks the division between the two subbasins—the Upper Basin and the Lower Basin—created by the division of the Colorado River Basin in the Colorado River Compact of 1922. This reference point is in the mainstream Colorado River in Arizona, 1 mile below the confluence of the Colorado River with the Paria River.

Lees Ferry Gaging Station—The site of the United States Geological Survey (USGS) stream gage (Lees Ferry Gaging Station) in Arizona on the Colorado River upstream of its confluence with the Paria River, downstream of Glen Canyon Dam. Also, the location of Colorado River ferry crossings (1873 to 1928).

limnology—Scientific study of physical characteristics and the biology of lakes, ponds, and streams.

load—Amount of electrical power or energy delivered or required at a given point.

Lower Basin (States)—Those parts of the states of Arizona, California, Nevada, New Mexico, and Utah within and from which waters drain naturally into the Colorado River below the Lee Ferry Compact Point in Arizona. The Colorado River Compact of 1922 divided the Colorado River system into two subbasins: the Upper Basin and the Lower Basin. *See also* Lee Ferry Compact Point.

Lower Division (States)—Arizona, Nevada, and California. The Colorado River Compact of 1922 divided the seven Colorado River Basin states into two groups: Upper Division States and Lower Division States. The Lower Division States are Arizona, Nevada, and California. *See also* Basin States.

magnitude—A number characteristic of a quantity and forming a basis for comparison with similar quantities, such as flows.

mean monthly flow—Average flow for the month, usually expressed in cubic feet per second.

mean sea level (msl)—The average height of the surface of the oceans and seas measured throughout all stages of the tidal cycle, determined from hourly readings of tidal height, and computed over a long (usually 19-year) period. It is used as a datum plane (that is, it serves as the reference surface from which elevations and depths are measured).

median—Middle value in a distribution, above and below which lie an equal number of values.

megawatt (MW)—One million watts of electrical power (capacity).

megawatt-hour (MWh)—One million watt-hours of electrical energy.

Mesozoic era—The second-to-last era of earth's geological history, lasting from about 252 to 66 million years ago, comprising the Triassic, Jurassic, and Cretaceous periods.

metalimnion—Thermal layering of water in lakes and streams. *See also* stratification.

milligram per liter (mg/L)—Equivalent to one part per million.

National Environmental Policy Act of 1969, as amended (NEPA)—Law requiring federal agencies to integrate environmental values into their decision-making processes by considering the environmental impacts of their proposed actions and reasonable alternatives to those actions. To meet this requirement, federal agencies prepare a detailed statement known as an environmental impact statement, or EIS.

National Register of Historic Places (NRHP)—The Nation's official list of cultural resources worthy of preservation. Authorized under the National Historic Preservation Act of 1966, the NRHP is part of a national program to coordinate and support public and private efforts to identify, evaluate, and protect our historic and archaeological resources. Properties listed on the NRHP include districts, sites, buildings, structures, and objects that are significant in American history, architecture, archaeology, engineering, and culture.

natural flow—The flow of any stream un-depleted by human activities.

non-system water—Waters originating from outside the Colorado River system.

normal condition—When the Secretary has determined that there is available for annual release 7.5 million acre-feet (maf) to satisfy consumptive use in the Lower Division States pursuant to Article II(B)(1) of the Consolidated Decree.

oligotrophic—A body of water characterized by low dissolved plant nutrient and organic matter, and rich in oxygen at all depths.

Paleontological resources—Any fossilized remains, traces, or imprints of organisms preserved in or on the earth's crust.

Paleozoic era (541–252 million years ago)—Means ancient life. The oldest animals on earth appeared just before the start of this era.

Pangea—A supercontinent that existed from about 300 to 200 million years ago and included most of the continental crust of the earth.

peak flow—Maximum instantaneous flow in a specified period of time.

peak load—Maximum electrical demand in a stated period of time.

penstock—Conduit pipe used to convey water from the reservoir through the dam under pressure to the turbines of a hydroelectric plant.

percentile—A statistical term. A descriptive measure that splits ranked data into 100 parts, or hundredths. For example, the 10th percentile is the value that splits the data in such a way that 10 percent of the values are less than or equal to the 10th percentile.

piscivorous—Habitually feeding on fish.

PM_{10} (PM10)—Particulate matter (PM) (dust particles) standard that includes particles with a diameter of 10 micrometers or less.

power—Electrical capacity generated, transferred, or used.

Present Perfected Right (PPR)—Many Colorado River water rights that originated as "perfected rights" specified in the 1964 United States Supreme Court Decree in the case of *Arizona v. California*. PPRs are the highest-priority Colorado River water rights that the 1964 Decree defines as those perfected rights existing on June 25, 1929 (the effective date of the Boulder Canyon Project Act of 1928).

priority—A ranking with respect to diversions of water relative to other water users.

probability—In this SEIS, the relative frequency with which a range of modeled values occurs. For example, the probability of Lake Mead's elevation exceeding 1,180 feet msl in June 2005 is equal to the number of modeled elevations greater than 1,180 feet msl in June 2005, divided by the total number of modeled elevations in June 2005.

public involvement—Process of obtaining citizen input into each stage of development of planning documents. Required as a major input into any EIS.

Quaternary period—A geologic time period that encompasses the most recent 2.6 million years, including the present day.

ramp rate—The rate of change in instantaneous output from a powerplant. The ramp rate is established to prevent undesirable effects due to rapid changes in loading or, in the case of hydroelectric plants, discharge.

rated head—Water depth for which a hydroelectric generator and turbines were designed.

reach—A specified segment of a river, stream, channel, or other water conveyance facility.

recruitment—Survival of young plants and animals from birth to a life stage less vulnerable to environmental change.

reregulating reservoir—A reservoir for reducing diurnal fluctuations resulting from the operation of an upstream reservoir for power production.

resampling—The digital process of changing the sample rate or dimensions of sampled data (for example, digital imagery or audio) by temporarily or areally analyzing and sampling the original data.

reserved water—In the case of Indian reservations, rights based on the doctrine of Indian reserved rights; in the case of federal establishments other than Indian reservations, a federal reservation of water for use on property under federal jurisdiction.

reservoir—A pond, lake, or basin, either natural or artificial, for the storage, regulation, and control of water.

return flow—The portion of water previously diverted from a river or stream and subsequently returned to that river or stream; it is available for consumptive use by others.

return flow credit—In the accounting of consumptive use in the Lower Basin, Colorado River water that is returned to the river and is available for consumptive use by others in the year in which it was diverted is credited against a water user's total diversions.

riffle—A stretch of choppy water caused by an underlying rock shoal or sandbar.

riparian—Of, on, or pertaining to the bank of a river, pond, or lake.

river mile (RM)—Numbered along the Colorado River from south to north starting with RM 0.0 at the Southerly International Boundary (SIB) with Mexico. Dam locations are noted at their respective river miles.

river outlet works—Dam structures that conduct water from the reservoir to the river without passing through a powerplant; also referred to as jet tubes, bypass tubes, or outlet works.

river stage—Water surface elevation of a river above a datum.

RiverWare™—A commercial river system simulation computer program that was configured to simulate operation of the Colorado River for this SEIS.

runoff—That part of the precipitation that appears in surface streams. It is the same as streamflow unaffected by artificial diversions, storage, or other works of humans in or on the stream channels.

sacred site—A specific location identified by a Native American Tribe as sacred for its religious significance to, or ceremonial use by, a Native American religion.

salinity—A term used to refer to the dissolved minerals in water; also referred to as total dissolved solids (TDS). *See also* total dissolved solids.

sandbar—A long, narrow deposition of sediment within a river.

Secretary—The Secretary of the Department of the Interior, and duly appointed successors, representatives, and others with properly delegated authority.

Section 10(a)(1)(B) permit—The section of the ESA that authorizes the Service to issue nonfederal entities a permit for the incidental take of endangered and threatened wildlife species. This permit allows the nonfederal entity to proceed with an activity that is legal in all other respects, but that results in the "incidental to, and not the purpose of, the carrying out of an otherwise lawful activity." *See also* take.

sediment—Unconsolidated solid material that comes from weathering of rock and is carried by, suspended in, or deposited by water or wind.

sediment load—Mass of sediment passing through a stream.

seepage—Relatively slow movement of water through a medium, such as sand.

shortage condition—When the Secretary has determined that there is available for annual release less than 7.5 maf to satisfy consumptive use in the Lower Division States pursuant to Article II(B)(3) of the Consolidated Decree.

spawn—To lay eggs, especially fish.

spills—Water releases from a dam in excess of powerplant capacity.

spillway—Overflow facility at a dam, usually consisting of a sill at the full-reservoir elevation.

spinning reserves—Available capacity of generating facilities synchronized to the interconnected electric system so that it can be called upon for immediate use in response to system problems or sudden load changes.

stage—Reservoir elevation.

standards—A means established by authority as a rule for the measure of quality, such as cosmetic effects (such as skin or tooth discoloration) or aesthetic effects (such as taste, odor, or color) in drinking water.

storage—Water artificially impounded in surface or underground reservoirs for future use. Water naturally detained in a drainage basin, such as groundwater, channel storage, and depression storage. The term "drainage basin storage" or simply "basin storage" is sometimes used to refer collectively to the amount of water in natural storage in a drainage basin. *See also* conservation storage and dead storage.

stormwater—Consists of water that originates from precipitation, such as heavy rain or snow.

stratification—Thermal layering of water in lakes and streams. Lakes usually have three zones of varying temperature: (1) epilimnion—top layer with essentially uniform warmer temperature, (2) metalimnion—middle layer of rapid temperature decrease with depth, and (3) hypolimnion—bottom layer with essentially uniform colder temperatures.

streamflow—The discharge that occurs in a natural channel. Although the term "discharge" can be applied to the flow of a canal, the word streamflow uniquely describes the discharge in a surface stream course. The term "streamflow" is more general than runoff, as streamflow may be applied to discharge whether it is affected by diversion or regulation.

suspended load—Sediment that is supported by the upward components of turbulence in a stream and that stays in suspension for an appreciable length of time.

surplus condition—When the Secretary has determined that there is available for annual release more than 7.5 maf to satisfy consumptive use in the Lower Division States pursuant to Article II(B)(2) of the Consolidated Decree.

system storage—The total volume of water available in the Colorado River Basin at a specific point in time.

system water—Waters originating from the Colorado River system.

tail water—Water immediately downstream of the outlet from a dam or hydroelectric powerplant where the water is more similar to that in the reservoir than farther downstream.

take—As defined by the ESA, a means to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct (16 United States Code 1531[18]).

thermocline—The zone of maximum change in temperature in a waterbody, separating upper (epilimnetic) from lower (hypolimnetic) zones.

threatened species—A species or subspecies that is likely to become endangered in the foreseeable future.

total dissolved solids (TDS)—Dissolved materials in the water, including ions such as potassium, sodium, chloride, carbonate, sulfate, calcium, and magnesium. In many instances, the term "TDS" is used to reflect salinity, since these ions are typically in the form of salts.

traditional cultural place—A type of historic property that is rooted in a community's history and important to that community's cultural identity.

tributary—River or stream flowing into a larger river or stream.

turbidity—Cloudiness of water, measured by how deeply light can penetrate into the water column from the surface.

turbine—A rotary mechanical device that uses water flow to turn and convert it into useful energy.

Upper Basin (States)—Those parts of the states of Arizona, Colorado, New Mexico, Utah, and Wyoming within and from which waters drain naturally into the Colorado River above the Lee Ferry Compact Point in Arizona. The Colorado River Compact of 1922 divided the Colorado River system into two subbasins: the Upper Basin and the Lower Basin. *See also* Lee Ferry Compact Point.

Upper Colorado River Commission—Commission established by the Upper Colorado River Compact of appointed members from the Upper Division States whose purpose is to secure the storage of water for beneficial consumptive use in the Upper Basin.

Upper Division (States)—Colorado, New Mexico, Utah, and Wyoming. The Colorado River Compact of 1922 divided the seven Colorado River Basin states into two groups: Upper Division States and Lower Division States. The Upper Division States are Colorado, New Mexico, Utah, and Wyoming. *See also* Basin States.

Visual resources—Physical features that make up the visible landscape (features such as land, water, vegetation, topography, and human-made features such as buildings, roads, utilities, and structures) as well as the response of viewers to those features.

Water Year—That period of 12 months ending September 30 of each year.

Waters of the United States—In accordance with the Clean Water Act, waters of the United States include (1) all waters that may be susceptible to use in interstate or foreign commerce; (2) all interstate waters, including interstate wetlands; (3) all other waters, such as intrastate lakes, rivers, streams (including intermittent streams), mud flats, sand flats, wetlands, sloughs, prairie potholes, wet meadows, playa lakes, or natural ponds, the use, degradation, or destruction of which could affect interstate or foreign commerce, including any such waters; (4) all impoundments of waters otherwise defined as waters of the United States; (5) tributaries of waters identified in this SEIS; (6) the territorial seas; and (7) wetlands adjacent to waters (other than waters that are themselves wetlands) identified in this SEIS.

watershed—The drainage area upstream of a specified point on a stream.

Index

This page intentionally left blank.

Appendix A
Overview of Colorado River Operations

This page intentionally left blank.