Chapter Four

4.1 Introduction

Chapter 4 presents the probable consequences (impacts or effects) of each of the alternatives described in Chapter 2 on the environmental resources described in Chapter 3. The potential effects of each action alternative compared to the No Action Alternative are presented for each potentially affected resource in this chapter, in the same order as described in Chapter 3.

The methodology and technical assumptions used to analyze the potential impacts to the Colorado River system (e.g., reservoir elevations, releases, flows) are described in Section 4.2. Additional methodologies and assumptions used to analyze specific resources are described in the appropriate resource section of Chapter 4.

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4.2 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 (e.g., reservoir elevations, reservoir releases, river flows) under the No Action Alternative for comparison to conditions under each action alternative. Due to uncertainties associated with future inflows into the system, multiple simulations were performed for each alternative in order to quantify the uncertainties in future conditions, and the modeling results are typically expressed in probabilistic terms.

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 to specific resource issues are identified and analyzed for each action alternative and compared to the potential effects to 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 A and Appendix M. For some of the resource analyses, additional modeling using other techniques was needed to analyze the potential effects to 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 4.

4.2.1 Alternatives Modeled

Five action alternatives and a No Action Alternative are considered in this Final EIS. The action alternatives are the Basin States, Conservation Before Shortage, Water Supply, and Reservoir Storage alternatives, and the Preferred Alternative. Each alternative includes specific assumptions with regard to the four operational elements of the proposed federal action: Shortage Guidelines, Coordinated Reservoir Operations, Storage and Delivery of Conserved Water, and ISG. Additional details with respect to the modeling assumptions used to represent each alternative are presented in this section, Appendix A, and Appendix M.

4.2.2 Period of Analysis

This Final EIS addresses guidelines that would be in effect for the interim period (2008 through 2026) for Lower Basin reservoir operations and the coordinated operations of Lake Powell and Lake Mead. In the modeling of the alternatives, all action alternatives are assumed to revert back to the assumptions used to represent the No Action Alternative beginning in 2027. Due to the potential for hydrologic effects of the action alternatives beyond the 19-year interim period, the hydrologic modeling for all alternatives extends through 2060.

4.2.3 Model Description

Future Colorado River system conditions under the No Action Alternative and the action alternatives were simulated using the Colorado River Simulation System (CRSS). 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. CRSS was originally developed by Reclamation in the early 1970s and was implemented in RiverWare™ in 1996.

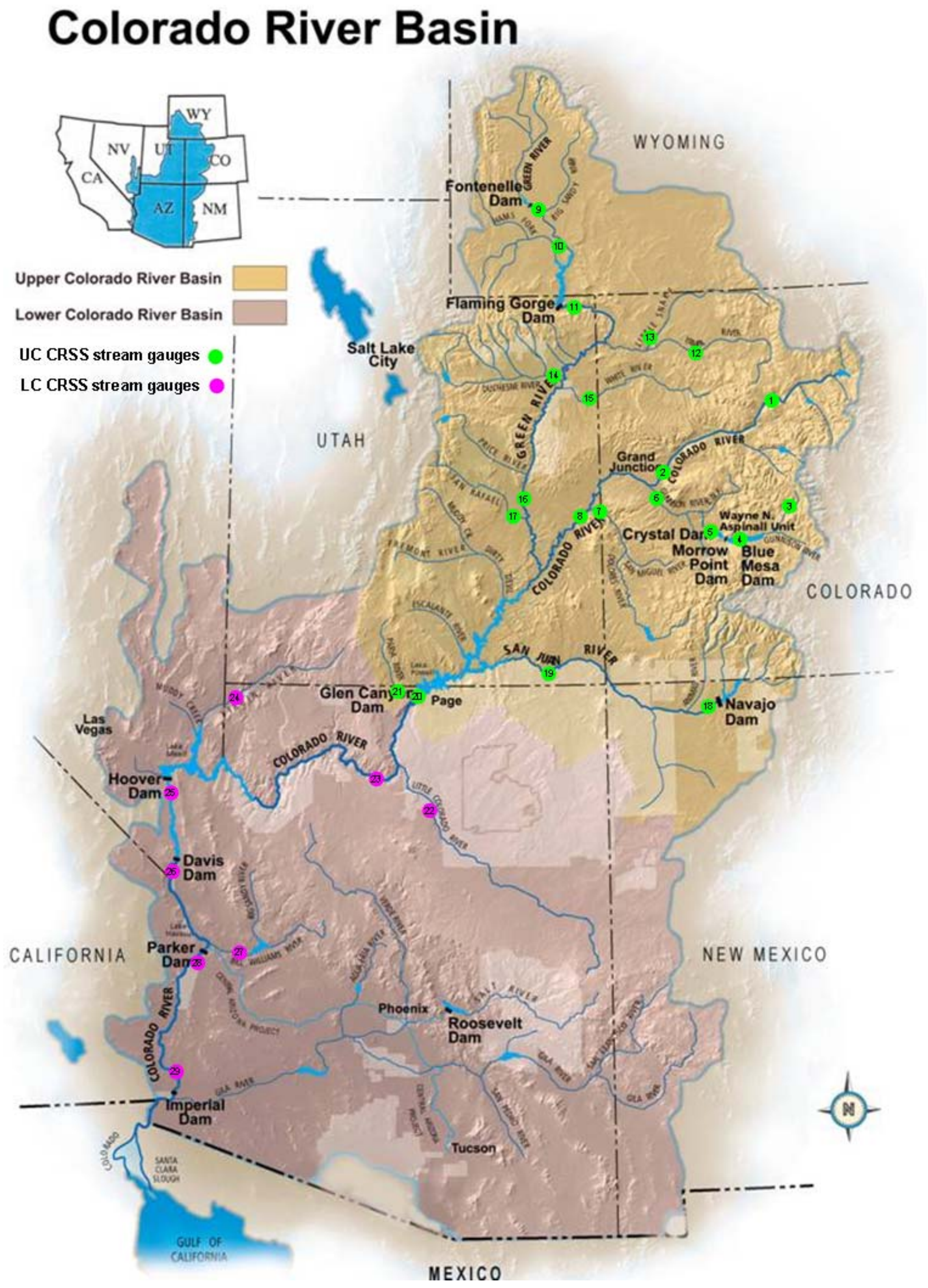
CRSS simulates the operation of the major reservoirs on the Colorado River and provides information regarding the projected future state of the system on a monthly basis in terms of output variables including the amount of water in storage, reservoir elevations, releases from the dams, the amount of 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 A. The model was used to project the future conditions of the Colorado River system on a monthly time-step for the period 2008 through 2060.

The input data for the model includes monthly natural inflows, various physical process parameters such as the evaporation rates for each reservoir, initial reservoir conditions on January 1, 2008, and the future diversion and depletion schedules for entities in the Basin States (Appendix C and Appendix D) and for Mexico. These future schedules were based on demand and depletion projections prepared and submitted by the Basin States. For purposes of this EIS, depletions (or water use) are defined as diversions from the river less return flow credits, where applicable (Section 3.4).

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 A.

The future hydrology used as input to the model consisted of samples taken from the historic record of natural flow in the river system over the 100-year period from 1906 through 2005 from 29 individual inflow points (or nodes) on the system. The locations of the hydrologic input sites are shown in Figure 4.2-1. This model and other methodologies used to generate future inflow scenarios are discussed in Section 4.2.5.

Figure 4.2-1
Colorado River Simulation System
Location of Hydrologic Inputs Sites within the Colorado River Basin



4.2.4 Model Uncertainty

Long-term planning models such as CRSS are typically used to project future river and reservoir conditions over a period of decades into the future. There are numerous inputs to, and assumptions made by, these models. As the period of analysis increases (for this EIS the analysis period is 53 years), the uncertainty in those inputs and assumptions also increases. Therefore, a large amount of uncertainty in the corresponding outputs is expected. Consequently, these models are not used to predict future conditions, but rather to project what might occur. When analyzing the potential hydrologic impacts from operational alternatives, most inputs, as well as other key modeling assumptions, are held constant for each alternative so as to isolate the differences due to each alternative. In this manner, the analyses for each alternative may be compared, and thus a relative comparison between alternatives can be made.

Although there are literally hundreds of inputs to and assumptions made by CRSS, the uncertainty of some will have greater effects on the outputs than others. Another way of thinking about this is to ask “what is the sensitivity of the output to a particular set of inputs or assumptions?” This question may be answered by conducting a sensitivity analysis whereby only one or perhaps a small number of inputs are varied in order to determine how sensitive the outputs are to that change. For example, in this Final EIS, two sensitivity analyses were performed that examine the sensitivity to variable future hydrologic scenarios (Appendix N) and to modeling assumptions with regard to future water delivery reductions to Mexico (Appendix Q).

There are several sources of uncertainty in the CRSS output including the representation and parameterization of physical processes such as reservoir evaporation and bank storage, the future diversion and depletion schedules for the entities throughout the Colorado River Basin, and the future inflows into the system. In addition, much of the input data are derived from actual measurements which have uncertainties associated with them. For example, the natural flows are based primarily on data acquired from flow gages which, when calibrated properly, have uncertainties on the order of five to ten percent. Although these data are generally the best available, all of these uncertainties limit the absolute accuracy of the model However, by holding most inputs constant, the relative comparisons between the modeled conditions are still valid.

Despite the differences in some of the modeling assumptions under the No Action Alternative and each action alternative, the future conditions of the Colorado River system (e.g., future Lake Mead and Lake Powell elevations) are most sensitive to future inflows. Observations over the period of historical record (1906 through present) show that inflow into the system has been highly variable from year to year, and over decades (Section 3.3). Because it is impossible to predict the actual future inflows into the system, a range of possible future inflows are analyzed and used to quantify the probability of occurrences of particular events (e.g., higher or lower lake elevations). This technique involves multiple simulations for each alternative, one for each future hydrologic sequence, and is the procedure followed for the hydrologic analysis in this EIS.

4.2.5 Future Hydrology

There are several accepted scientific methods for projecting possible future inflow sequences. These methods include resampling the historical record (either from the measured record or a derived record using a "proxy" such as tree-ring data), deriving future inflow data by preserving key statistics of the historical record while adding a random component, and using physically-based models to simulate runoff using precipitation, temperature, and other climate data. For this EIS, Reclamation primarily utilized the existing historical record of natural flows to create a number of different future hydrologic sequences using a resampling technique known as the Indexed Sequential Method (ISM). The ISM provides the basis for quantification of the uncertainty and an assessment of the risk with respect to future inflows and is based upon the best available measured data. ISM is well-documented and has been widely accepted by Colorado River stakeholders (Reclamation 1985; Ouarda et al. 1997). These sequences were used to perform a series of simulations and the output was analyzed to quantify the uncertainty due to hydrologic variability for each variable of interest.

4.2.5.1 Computational Procedures Using the Historical Natural Flow Record

In its current configuration, the CRSS model requires hydrologic inputs at 29 sites throughout the Colorado River system: 20 sites in the Upper Basin upstream of and including the Lees Ferry gaging station in Arizona, and an additional nine sites in the Lower Basin. The locations of these 29 sites are shown in Figure 4.2-1. This level of hydrologic detail is needed to simulate the operation of the major reservoirs throughout the system including the reservoirs on the major sub-basins (the Gunnison, Green, and San Juan rivers)[1].

Reclamation uses data collected from the USGS and other gage sites[2], consumptive use records, records of reservoir releases, and other data to compute the natural flow at each of the 29 sites. In the mid-1990s, Reclamation initiated an on-going program to review and update the natural flow record, document the methodologies used to compute the natural flows, and extend the record as soon as practicable at the conclusion of each year to ensure that the best available information is always available. At this time, the natural flow record consists of monthly data for the 29 sites from 1906 through 2005, a period of 100 years. Additional information, documentation, and the natural flow data are available at http://www.usbr.gov/lc/region/g4000/NaturalFlow/index.html.

For the ISM, each future inflow scenario is generated by cycling through the historical natural flow record. For example, assuming a 100-year historical record (1906 through 2005) and that the model projects 53 years into the future (2008 through 2060), the

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[1] Although these sub-basins are not a part of the geographic scope (Section 3.2), modeling of the reservoirs (e.g., Flaming Gorge) is necessary to simulate the future inflows into Lake Powell.

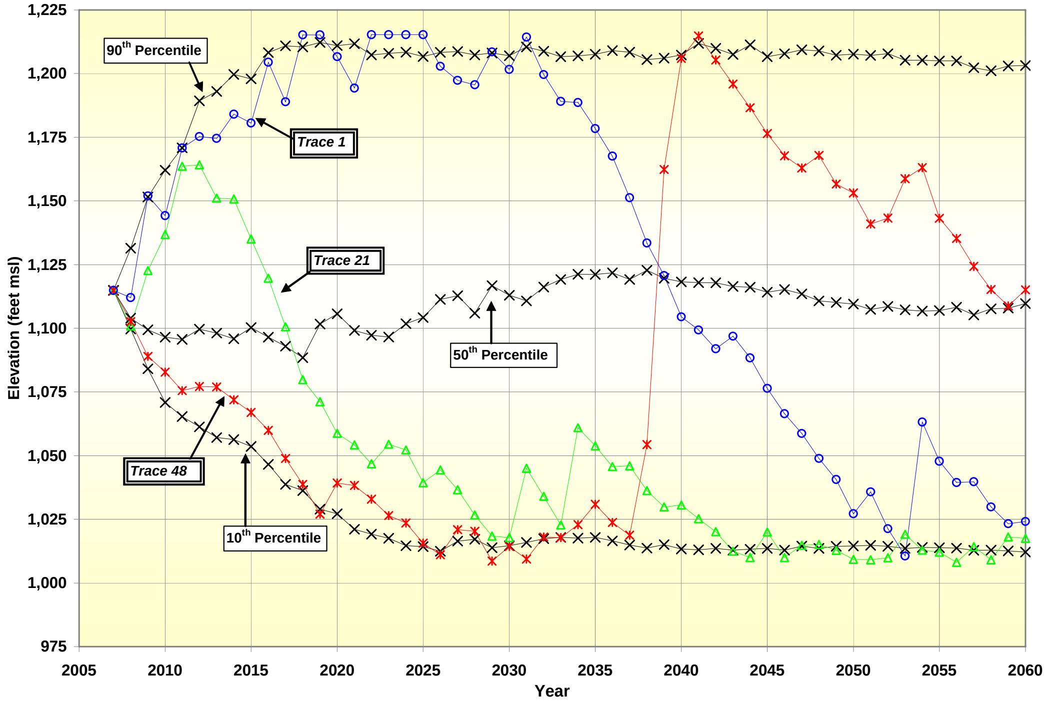
[2] Reclamation provides funding to the USGS to assist in maintaining and expanding, as appropriate, gage sites throughout the Colorado River Basin. Reclamation also installs, maintains, and operates additional gage sites in the Lower Basin.

first inflow sequence would be comprised of the series of historical natural flows from 1906 through 1958; the second inflow sequence would utilize the series of historical natural flows from 1907 through 1959; the last sequence would utilize the series of historical natural flows beginning in 2005, with historical natural flows from 1906 through 1957 appended to the end to form a complete (53-year) sequence.

The result of the ISM applied to the historical record is a set of output (referred to as traces) for 100 separate simulations for each alternative that is analyzed and compared to similar simulation results for the other alternatives. The projections of future hydrologic conditions are probabilistic, based on the hydrologic variability observed in the 100-year historic record which includes periods of severe drought as well as periods with above-average flow.

Figure 4.2-2 presents an example of the output of this technique for future Lake Mead elevations under the No Action Alternative. Three of the 100 traces are shown. Trace 1 is the output for the hydrologic sequence that begins in 1906. Trace 21 is the output for the hydrologic sequence that begins in 1926. Trace 48 is the output for the hydrologic sequence that begins in 1953. Hydrologic inflows over the 100-year record have been highly variable and these traces are representative of that variability. The traces clearly illustrate that future elevations at Lake Mead are highly dependent upon future hydrologic inflows, resulting in large uncertainty with regard to projections of future conditions. This uncertainty may be quantified, however, through the analysis of the 100 traces. An example of one type of analysis is also presented in Figure 4.2-2, where the 90^{th}, 50^{th}, and 10^{th} percentiles of the 100 outputs in each year have been computed and added to the figure.

Figure 4.2-2
Lake Mead End-of-December Elevations Under the No Action Alternative
90th, 50th and 10th Percentile Values



4.2.5.2 Reclamation's Research and Development Efforts

Although the ISM methodology provides the means to compare the alternatives under a wide range of future flow conditions, it is possible that future flows may include periods of wet or dry conditions that are outside the range of sequences observed in the historical record, particularly as a result of climate change and increased hydrologic variability.

The Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), published in April 2007, presented a selection of key findings regarding projected changes in precipitation and other climate variables as a result of a range of climate change scenarios projected by the IPCC over the next century. Although annual average river runoff and water availability are projected to decrease by ten to 30 percent over some dry regions at mid-latitudes, information with regard to potential impacts on specific river basins is not included. Recently published projections of potential reductions in natural flow on the Colorado River Basin by the mid 21st century range from approximately 45 percent by Hoerling and Eischeid (2006), to approximately six percent by Christensen and Lettenmaier (2006). A recent analysis of future precipitation minus evaporation (a surrogate for runoff) in the basin suggests an "imminent transition to a more arid climate in southwestern North America" (Seager et al. 2007).

While these projections are of great interest, additional research is both needed and warranted to quantify the uncertainty of these estimates in order to better understand the risks of current and future water resource management decisions. The uncertainties include the actual uncertainty in the climate response as well as the uncertainty due to differences in methodological approaches and model biases.

Recognizing this need, particularly in light of the drought in the Colorado River Basin, Reclamation's Lower Colorado (LC) Region initiated a multi-faceted research and development program in 2004 to enable the use of other methods for projecting possible future inflow sequences for Colorado River planning studies. The research and development effort has been designed to provide information for the near-term (e.g., some facets have already been completed and the information has been used in the Final EIS), as well as for the longer-term that involves collaboration with other research organizations (e.g., National Oceanic & Atmospheric Administration (NOAA) and USGS). This effort has two major thrusts:

- ♦ collaboration with other federal agencies and universities to conduct research to gain knowledge and understanding of the potential impacts of climate change and climate variability on the Colorado River; and
- ♦ improvement of Reclamation's decision support framework, including modeling and data handling capabilities, in order to utilize the new information when it becomes available.

Contributions from this research and development program have been invaluable in advising the analysis and content in the Final EIS to address future hydrologic variability and the potential for increased hydrologic variability due to climate change. These and other efforts will continue and will provide Reclamation the ability to incorporate new additional climate change information, as it becomes available, into future Colorado River Basin planning studies.

At this time, there are five key components to the research and development program:

1) Sponsorship of National Research Council's (NRC) Committee on the Scientific Bases of Colorado River Basin Water Management in collaboration with the California Department of Water Resources, the MWD, the SNWA, and the NRC's Water Science and Technology Board.

   This study culminated in a report published in early 2007, titled "Colorado River Basin Water Management: Evaluating and Adjusting to Hydroclimatic Variability." The executive summary of this report is included as Appendix T. Key conclusions and recommendations in the area of hydroclimatic data and sciences included:

   – There has been a trend of increasing mean temperatures across the Colorado River Basin over the 20th century into the 21st century. Many climate model projections show that this trend will continue. There is less consensus regarding future trends in precipitation and runoff. Several hydroclimatic studies project that increasing temperatures will result in significant decreases in precipitation and runoff while other studies suggest increases in future flows. However, the preponderance of the scientific evidence suggests warmer future temperatures will reduce future streamflow and water supplies and contribute to increased severity, frequency, and duration of future droughts.

- Recent studies based on tree-ring data affirm the large year-to-year variations in streamflow as observed in the historical record and demonstrate that multidecadal and centennial fluctuations of mean streamflow have occurred in the past. Given both natural and human-induced climate changes, fluctuations in the mean streamflow are likely to continue in the future. Furthermore, the range of natural variability derived from the tree-ring records reveals greater hydrologic variability than reflected in the gaged record, particularly with regard to drought. These observations coupled with projections of future decreasing streamflows suggest that future droughts will recur and may exceed the severity of the droughts observed in the historical record.

- Measured values of streamflow in the Colorado River Basin are critical to providing the essential information for sound water management decisions. Availability of sufficient resources should be ensured in order to maintain and where appropriate, expand the USGS gaging network.

2) Collaboration with the University of Arizona, the Arizona Water Institute, the Arizona Water Resources Research Center, and the Laboratory of Tree Ring Research on a project focused on integrating improved water supply predictive capability into Colorado River Basin policy and management to enhance water supply reliability.

Reclamation has been participating in this collaborative effort since its inception in July 2004 and the project is anticipated to be concluded in 2008. It is a multi-pronged approach that includes:

- assessing the potential for enhanced modeling capability associated with use of paleoclimatic data, climate forecasts and climate change predictions, and the water management tools that need to be developed to use that information;

- identifying strategies to better utilize paleoclimatology, climate forecasts and climate change predictions to improve water supply predictive capacity;

- evaluating existing management tools to translate improved predictive capacity into enhanced supply reliability for water users; and

- developing practical supply reliability strategies for use by water users and other stakeholders.

A significant aspect of this research involves the evaluation of the potential use of enhanced tree-ring information to improve predictive capability on the Colorado River. An important contribution has been an extension of the long-term record of flows on the Colorado River at Lees Ferry back to 762 A.D., adding to the understanding of historic climate and flow patterns and improving Reclamation's capability to quantify the uncertainty of future hydrologic conditions. In addition, existing tree-ring information was synthesized using published tree-ring reconstructions (Stockton and Jacoby 1976; Hidalgo et al. 2000). These studies resulted in two key publications: i) Medieval Drought in the Upper Colorado River Basin (Meko et al. 2007); and ii) Updated Streamflow Reconstructions for the Upper Colorado River Basin (Woodhouse et al. 2006).

The tree-ring data resulting from this work has been used to analyze the sensitivity of the hydrologic resources to alternative future hydrologic scenarios (Appendix N).

Ongoing work includes the assessment of techniques for including additional climate prediction information, including the use of downscaled and bias-corrected climate predictions to generate alternative hydrologic scenarios at the spatial scales needed for CRSS. Additional information with regard to this work available at http://www.ag.arizona.edu/AZWATER/EWSR.

3) Collaboration with the University of Colorado and the Center for Advanced Decision Support for Water and Environmental Systems (CADSWES) on a project focused on assessing the current drought on the Colorado River in terms of its magnitude and likelihood of recurrence and investigative techniques that can be used to simulate streamflow scenarios that are consistent with the current drought and other realistic, and possible more severe, future drought conditions.

   Reclamation began this on-going collaboration effort in the fall of 2004. The major activities include:

   – Research and development of non-parametric methods for the disaggregation of streamflows at one site, both temporally and spatially, to other sites on the Colorado River Basin. This allows for the use of projections of future inflow at Lees Ferry (e.g., from tree-ring reconstructions) in CRSS.

   – Estimating and analyzing (particularly with regard to the temporal variability) the transition probabilities (i.e. probability of transitioning into a dry state in the following year from a wet state in the current year) from long records of tree-ring reconstructions of streamflows.

   – Generating new synthetic sequences of the state of the system (i.e., wet or dry) and consequently, the probabilities of long dry spells using the transitional probabilities. Conditioned on the state of the system, the flow magnitudes can be generated by conditional resampling from the historical record.

   Future work will include investigation of possible links between the historical transition probabilities and large-scale climate features of El Niño Southern Oscillation (ENSO), Pacific Decadal Oscillation (PDO), and the Atlantic Multidecadal Oscillation (AMO). Such links might provide a technique to condition future inflow sequences on information from climate models regarding these large-scale features.

The key findings and results of this research have been recently published: A Stochastic Nonparametric Technique for Space-time Disaggregation of Streamflows, Prairie et al. 2007. These methods were used to analyze the sensitivity to the hydrologic resources of alternate future hydrologic scenarios developed using the most recent tree-ring data from the University of Arizona (Appendix N).

4) Formation of a climate technical work group[3] to assess the state of knowledge with regard to climate change and modeling for the Colorado River Basin and to prioritize future research and development needs.

This work culminated in a report that has been included in Appendix U, titled Review of Science and Methods for Incorporating Climate Change Information into Reclamation's Colorado River Basin Planning Studies. [4] Key conclusions and recommendations include:

- Climate models project that temperatures will increase globally by one to two degrees Celsius in the next 20 to 60 years. Although the downscaling of global temperature increase to the Colorado River Basin is less certain, it is reasonable to expect that temperatures will increase. Regional precipitation response is even less certain;

- The potential impacts of climate change on the Colorado River Basin have been a subject of research for several decades. Recent studies have been refined in several ways including how the climate change models output is bias-corrected and downscaled to the spatial resolution needed for planning studies. Due to advances in knowledge, technical abilities, and other factors, not all past studies retain the same significance today;

- Although paleoclimatic information may not necessarily represent future climate scenarios, this information may be useful in framing assumed variability in future hydrologic sequences, particularly with respect to drought potential;

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[3] Organizations represented in the work group include the University of Colorado (NOAA - Western Water Assessment), the University of Arizona, the University of Nevada – Las Vegas, the University Corporation for Atmospheric Research, Reclamation, and Hydrosphere Consultants, Inc.

[4] This report will be a forthcoming Reclamation publication with no change to content; however, the formatting will be changed from that used in Appendix U.

– System storage is very sensitive to changes in mean inflows as well as sequences of wet and dry years, highlighting the importance of properly investigating changes in both mean and variability in planning studies;

– For studies and management decisions involving shorter look-ahead horizons (e.g., less than 20 years), interannual to decadal variability may be a more significant uncertainty than that associated with near-term projected climate change. Evaluating the state of interannual/interdecadal oscillation phenomena such as ENSO, PDO, and AMO may add significant information with respect to the risk due to increased variability; and

– For longer look-ahead horizons (20+ years), further research and development is needed to translate climate protections from General Circulation Models (GCMs) to the spatial scales necessary for use in Colorado River planning studies.

In addition, several recommendations for research and development were made. These recommendations are currently being reviewed and prioritized.

5) Improvements and updates to Reclamation's Colorado River natural flow database and decision-modeling framework (including the CRSS model and associated data handling and analysis tools).

The natural flow record is critical to the understanding of the hydrology of the past 100 years and provides the basis for understanding future changes. Reclamation has an on-going program to ensure that this data is the best available. Additionally, all of the new methods have the capability to produce large numbers of possible future inflow sequences (on the order of 1000 or more possibilities), requiring sophisticated data handling, data processing and analysis tools. Furthermore, refinements to the current CRSS model that are needed to incorporate operating policies on key sub-basins have been evolving through other environmental compliance efforts (e.g., the Record of Decision for Navajo Reservoir operations in July 2006), requiring modification of the rules used by CRSS to simulate the operation of the major reservoirs in each sub-basin. These improvements are on-going.

4.2.5.3 Summary

Based on the current inability to precisely project future impacts of climate change to runoff throughout the Colorado River Basin at the spatial scale needed for CRSS, Reclamation based its hydrologic analysis for this EIS primarily on the resampled historical record. However, in order to understand the potential effects of future inflow sequences outside the range of historical flows (i.e., future sequences with increased variability including the severity, frequency, and duration of droughts), particularly during the 19-year period of the application of the proposed federal action, Reclamation analyzed the sensitivity of the hydrologic resources (including reservoir storage, reservoir releases, and river flows) to hydrologic scenarios derived from alternative methodologies (including stochastic hydrology methods and paleo-reconstruction methods) in the Draft EIS. An additional analysis has been added to Appendix N in the Final EIS that incorporates a newly published tree-ring reconstruction of hydrologic inflows at Lees Ferry (Meko et al. 2007) that extends the estimate of annual flow at Lees Ferry back to the year 762, a record length of 1,244 years.

Although precise estimates of the future impacts of climate change to runoff throughout the Colorado River Basin at appropriate spatial scales are not currently available, these impacts may include decreased mean annual flow and increased variability, including more frequent and more severe droughts. Furthermore, even without precise knowledge of the effects on runoff, increasing temperatures alone would likely increase losses (e.g., evapotranspiration and sublimation), resulting in reduced runoff.

Acknowledging the potential for impacts due to climate change and increased hydrologic variability, the Secretary proposes that these guidelines be interim in duration and extend through 2026, providing the opportunity to gain valuable operating experience for the management of Lake Powell and Lake Mead, particularly for low reservoir conditions, and improve the basis for making additional future operational decisions, whether during the interim period or thereafter. In addition, the Preferred Alternative has been crafted to include operational elements that would respond if potential impacts of climate change and increased hydrologic variability are realized. In particular, the Preferred Alternative includes a coordinated operation element that allows for the adjustment of Lake Powell’s release to respond to low reservoir storage conditions in Lake Powell or Lake Mead as described in Section 2.7 and Section 2.3. In addition, the Preferred Alternative will enhance conservation opportunities in the Lower Basin and the retention of water in Lake Mead through adoption of the ICS mechanism. Finally, the Preferred Alternative includes a shortage strategy at Lake Mead that would result in additional shortages being considered, after appropriate consultation, if Lake Mead elevations drop below 1,025 feet msl.

4.2.6 Post-processing and Interpretation Procedures

The physical, biological, and socioeconomic analyses in the Final EIS required the sorting and arranging of various types of model output data into tabulations or plots of specific operational conditions or parameters at various locations on the system. This was done through the use of statistical methods and other numerical analyses.

The hydrologic model generated data on a monthly time-step for over 300 points (or nodes) on the Colorado River system. Furthermore, through the use of ISM, the model generated 100 possible outcomes for each node for each month during the interm period (2008 through 2060). These very large data sets generated for each alternative can be visualized as three-dimensional data “cubes” with the axes of time, space (or node) and trace (or outcome for each future hydrology). The data were aggregated to reduce the volume of data and to facilitate comparison of the alternatives. The type of aggregation varies depending upon the needs of the particular resource analysis. The post-processing techniques used for this Final EIS fall into two basic categories: those that aggregate in time, space, or both, and those that aggregate the 100 possible outcomes.

For aggregation of data in time and space, simple techniques were employed. For example, deliveries of Colorado River water to all California diversion nodes in the model were summed to produce the total delivery to the state for each year. Similarly, lake elevations were chosen on an annual basis (i.e., end of December) to show long-term lake elevation trends as opposed to short-term fluctuations. In other analyses, since the proposed interim period is 2008 through 2026, those analyses found it important to aggregate the data over that period of time and compared the aggregation over the remaining years (2027 through 2060). The particular aggregation used is noted in the methodology section for each resource, where applicable.

Once the appropriate temporal and spatial aggregation was chosen, standard statistical techniques were used to analyze the 100 possible outcomes for a fixed time or particular temporal span. Statistics that were generated included the mean, standard deviation, and percentiles.

Percentiles were determined by simply ranking the outcomes at each time-step (from highest to lowest) and determining the value at the specified percentile. For example, if end-of-calendar year Lake Mead elevations are ranked for each year, the 50th percentile (median) outcome for a given year is the elevation for which half of the values are below and half are above that elevation. Similarly, the 10th percentile value is the elevation for which 10 percent of the values are lower and 90 percent are higher. This statistical method is used to view the results of all hydrologic sequences in a compact manner yet maintains the variability at high, medium, and low reservoir elevations that may be lost by averaging the results of all traces. Several presentations of the ranked data are then possible. For example, a graph (or table) may be produced that is used to compare the 90th percentile, 50th percentile, and 10th percentile outcomes from 2008 through 2060 for the No Action Alternative and the action alternatives. A statistic such as the 10th percentile is not the result of any one hydrologic trace. However, no historical sequence produced the 10th percentile. Such a statistic provides information with regard to the probability (e.g., a 10 percent probability) of the variability of interest being at or below the 10th percentile value in a specified year. However, the statistic cannot be used to understand the probability of remaining at that value in subsequent years.

4.2.7 Modeling Assumptions Common to All Alternatives

In addition to the specific operating rules necessary to model each of the alternatives (discussed in Chapter 2, Appendix A, and in 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:

- all simulations were performed with a start year of 2008 and a simulation length of 53 years (2008 through 2060);
- each action alternative was assumed to be in effect for the interim period which extends from 2008 through 2026. For modeling purposes, the operating rules for all action alternatives are assumed to revert to the rules of the No Action Alternative after 2026;

- the initial conditions for the Upper Basin and Lower Basin reservoirs reflect the 2007 end-of-calendar year (EOCY) elevations as projected by the June 2007 24-Month Study. The Lake Powell and Lake Mead initial elevations (starting condition) in the model were 3,596.77 feet msl and 1,114.85 feet msl, respectively. These starting conditions were updated in the Final EIS from those used in the Draft EIS as additional information became available. Starting conditions for all reservoirs used in both the Draft EIS and the Final EIS are detailed in Appendix A;

- future hydrology was generated from the 100-year (1906 through 2005) historic record of calculated natural flows at 29 separate inflow points in the Colorado River watershed using the ISM. One hundred simulations were performed for each alternative;

- the current Upper Basin reservoir operating rules, with the exception of Lake Powell, are identical under all alternatives. Under the action alternatives, the operation of Lake Powell reflects the coordinated operations strategy of each respective alternative during the interim period;

- future water demands for Upper Division water users are based on depletion projections prepared by the Upper Division states in coordination with the Upper Colorado River Commission and Reclamation, and are as published in the SIA Final EIS (Volume II, Appendix G). These depletion schedules are also provided in Appendix C;

- Lake Mead flood control procedures are always in effect;

- except during flood control conditions, Lake Mead is operated to meet downstream demands under the water supply condition (Normal, Surplus, or Shortage condition) in effect in a particular year;

- future water demands for Lower Division water users are based on depletion schedules prepared by the Lower Division states and published in the SIA Final EIS (Volume II, Appendix G) with some exceptions. Depletion schedules under a Normal Condition for IID, CVWD, and MWD are those specified in the Colorado River Water Delivery Agreement and include accelerated Inadvertent Overrun Paybacks and any subsequent changes in payback schedules. Depletion schedules for all Arizona users were provided by the Arizona Department of Water Resources for this EIS effort. These depletion schedules are provided in Appendix D;

- if Lake Mead elevations fall below 1,000 feet msl, delivery to SNWA is reduced to zero. This reflects the limitations of the SNWA intakes which are used to pump water from Lake Mead;

- Lake Mohave and Lake Havasu are operated in accordance with their existing rule curves;

- water deliveries to Mexico are pursuant to the requirements of the 1944 Treaty. This provides annual deliveries of 1.5 maf to Mexico and up to 1.7 maf during Lake Mead flood control release conditions;

- Mexico's principal diversion is at Morelos Diversion Dam where most of its Colorado River apportionment of 1.5 mafy is diverted. In practice, up to 140 kafy is delivered to Mexico near the SIB. The model, however, extends to just south of the NIB to include the Morelos Diversion Dam and accounts for the entire 1944 Treaty delivery at that point;

- for 2008 and 2009, the model sets the delivery schedule to Mexico at the NIB to 1.577 mafy. The additional 77 kafy reflects the average annual volume of non-storable flows that are delivered to Mexico for the period 1964 through 2005, excluding years when there were flood control releases on the mainstream Colorado River or Gila River;

- beginning in 2010, the proposed Drop 2 Storage Reservoir is assumed to be in operation and is assumed to conserve an average of 69 kafy, reducing the average annual volume of non-storable flows that are delivered to Mexico from 77 kafy to 8 kafy;

- the bypass of return flows from the Welton-Mohawk Irrigation and Drainage District to the Cienega de Santa Clara in Mexico is assumed to be 109 kafy, the historical average for the period 1990 through 2005, and is not counted as part of the 1944 Treaty delivery;

- except under the Conservation Before Shortage and the Reservoir Storage alternatives, replacement of the bypassed water is not assumed to occur in the future. The United States recognizes that it has an obligation to replace, as appropriate, the bypass flows, and the assumptions made herein for modeling purposes do not necessarily represent the policy that Reclamation will adopt for replacement of bypass flows. The assumptions made with respect to modeling the bypass flows are intended only to provide a thorough and comprehensive accounting of the Lower Basin water supply. The United States is exploring options for replacement of the bypass flows, including options that would not require operation of the Yuma Desalting Plant; and

- for modeling purposes, the Yuma Desalting Plant is not assumed to operate over the modeling period.

Assumptions with regard to reduction of deliveries to the Lower Division states and Mexico are as described below.

4.2.7.1 Shortage Sharing and Water Delivery Reduction Assumptions

A summary of modeling assumptions with respect to the reduction of deliveries to the Lower Division states and Mexico was provided in Section 2.2. These modeling assumptions are identical for all alternatives and are explained further in this section. Shortage sharing assumptions within a particular state are detailed in Section 4.4 and in Appendix G.

It was assumed that shortages would be allocated to each Lower Division state. Two sets of percentages were assumed depending upon the amount of total Lower Basin shortage to be applied. Shortages less than or equal to the magnitude that would cause Arizona 4th priority users to be reduced to zero are termed Stage 1 shortages. This magnitude is dependent upon the scheduled depletions for the Arizona 4th priority users (post-September 30, 1968 contractors, including CAP), which vary over the period of analysis. In a Stage 2 shortage, additional shortages above that magnitude are applied.

In order to assess the potential effects of the proposed federal action in this Final EIS, certain modeling assumptions were used that display projected water deliveries to Mexico. These modeling assumptions assume that Mexico would share proportionately in Lower Basin shortages. An analysis that considers the sensitivity of the hydrologic resources to these assumptions is presented in Appendix Q. In that analysis, a different set of modeling assumptions were used that assume that Mexico would share proportionally in both Upper Basin and Lower Basin shortages.

Allocation of Colorado River water to Mexico is governed by the 1944 Treaty. The proposed federal action is for the purpose of adopting additional operational guidelines to improve the Department's annual management and operation of key Colorado River reservoirs for an interim period through 2026. As such, Reclamation's modeling assumptions are not intended to constitute an interpretation or application of the 1944 Treaty or to represent current United States policy or a determination of future United States policy regarding deliveries to Mexico. The United States will conduct all necessary and appropriate discussions regarding the proposed federal action and implementation of the 1944 Treaty with Mexico through the IBWC in consultation with the Department of State.

Therefore, for purposes of modeling and the resource analyses, the shortage-sharing percentages were computed as follows:

Stage 1 Shortage Sharing Modeling Assumptions. Shortages are first imposed under Stage 1 and would be applied to the most junior users within Arizona (those with post-1968 water rights, i.e., 4th and 5th priority rights within Arizona), Nevada and Mexico. Stage 1 shortages would continue until the deliveries to the post-1968 water rights holders in Arizona (including CAP) are reduced to zero. The maximum amount of Stage 1 shortages during the period of analysis is dependent on the scheduled depletions for the post-1968 water rights holders and decreases in time (2008 through 2060) from approximately 1.8 maf to 1.7 maf[5].

The assumed Stage 1 shortage sharing percentages are explained in Table 4.2-1.

Stage 2 Shortage Sharing Modeling Assumptions. After deliveries to those with 4th and 5th priority rights within Arizona are reduced to zero, it is assumed that any additional delivery reductions would be distributed to Arizona, California, Nevada, and Mexico. The assumed Stage 2 shortage sharing percentages are explained in Table 4.2-2. Under a Stage 2 Shortage, the total Lower Basin shortage is the sum of the computed Stage 1 and Stage 2 shortage amounts.

Table 4.2-1
Modeling Assumptions for Distribution of Stage 1 Shortages

Entity	Percentage of Stage 1 Shortage	Calculation
Arizona[1]	80	▪ Computed assuming that Arizona takes the remaining amount of shortage after Nevada and Mexico take their respective shares ▪ Calculated as: 1.0 – 0.1667 – 0.0333 = 0.80 or 80.0 percent
California	0	▪ Does not receive shortage under Stage 1
Nevada	3.33	▪ Computed as a ratio of Nevada's allotment to the total allotments of the Lower Division states and Mexico ▪ Calculated as: 0.3 maf / 9.0 maf = 0.0333 or 3.33 percent
Mexico[2]	16.67	▪ Computed as a ratio of Mexico's allotment to the total allotments of the Lower Division states and Mexico ▪ Calculated as: 1.5 maf / 9.0 maf = 0.1667 or 16.67 percent

1. *Within CAP, Ak-Chin and Salt River Pima-Maricopa Indian Community tribes have contracts for the delivery of 72 kaf that is not reduced until a Stage 2 Shortage is applied as the associated water rights have a pre-1968 priority date.*
2. *These modeling assumptions do not reflect policy decisions and are not intended to constitute an interpretation or application of the 1944 Treaty.*

[5] Although these assumptions are common to all alternatives, shortages of high magnitudes either occur infrequently or not at all for all alternatives (Section 4.4.4).

Table 4.2-2
Modeling Assumptions for Distribution of Stage 2 Shortages

Entity	Percentage of Stage 2 Shortage	Calculation
Arizona	15-20	▪ The percentage changes as Arizona's 4th priority use schedule changes and ranges between 15 and 20 percent ▪ Computed as a ratio of Arizona's allotment less the amount of shortage applied to Arizona under Stage 1, to the total allotments of the Lower Division states and Mexico less the total amount shorted to users under Stage 1 ▪ Calculated as: (2.8 – Arizona Stage 1 shortage) / (9.0 – total Stage 1 shortage)
California	60-65	▪ California shortage sharing percentage changes as Arizona's 4th priority use schedule changes and ranges between 60 and 65 percent ▪ Computed assuming that California takes the remaining amount of the additional shortage ▪ Calculated as: 1.0 – 0.1667 – 0.0333 – Arizona's Stage 2 percentage expressed as a fraction
Nevada	3.33	▪ Computed as a ratio of Nevada's allotment less the amount of shortage applied to Nevada under Stage 1, to the total allotments of the Lower Division states and Mexico less the amount shorted to users under Stage 1 ▪ Calculated as: (0.3 – Nevada Stage 1 shortage) / (9.0 – total Stage 1 shortage) = 0.0333 or 3.33 percent
Mexico[1]	16.67	▪ Computed as a ratio of Mexico's allotment less the amount of shortage applied to Mexico under Stage 1, to the total allotments of the Lower Division states and Mexico less the total amount shorted to users under Stage 1 ▪ Calculated as: (1.5 – Mexico Stage 1 shortage) / (9.0 – total Stage 1 shortage) = 0.1667 or 16.67 percent

1. *These modeling assumptions do not reflect policy decisions and are not intended to constitute an interpretation or application of the 1944 Treaty.*

4.2.7.2 Shortage Sharing Between Arizona and Nevada

Pursuant to the Arizona Nevada Shortage Sharing Agreement dated February 9, 2007, Arizona and Nevada have agreed to share shortages during the interim period (2008 through 2026) between the two states by specified amounts at each discrete level of total Lower Basin shortage. The shortage amounts that are allocated to Arizona and Nevada pursuant to the Arizona Nevada Shortage Sharing Agreement are shown in Table 4.2-3.

In the Draft EIS, the distribution of shortages among the Lower Division states was made according to assumed percentages (Section 2.2.1). This modeling assumption allocated 80 percent and 3.33 percent of the total Lower Basin shortage amount to Arizona and Nevada, respectively. Reclamation used the same assumption in the Final EIS. This modeling assumption is common among all alternatives and enabled Reclamation to model the distribution of shortages to the Lower Division states for volumes different than those considered in the Arizona Nevada Shortage Sharing Agreement.

Table 4.2-3 provides a comparison of the shortage amounts to Arizona and Nevada based on the shortage distribution assumptions used in the modeling to the amounts specified in the Arizona-Nevada Shortage Sharing Agreement. As shown on this table, the shortage amounts allocated to Arizona are the same under both methodologies and the shortage amounts allocated to Nevada differ slightly. Also, these differences exist only when the total Lower Basin shortages shown in this table occur. Additional details on the assumptions used to model the distribution of shortages between the Lower Division states are provided in Appendix A and Appendix G.

Table 4.2-3
Comparison of Shortage Allocation to Arizona and Nevada for the Specified Lower Basin Shortage
Differences Between Modeling Assumptions and Arizona-Nevada Shortage Sharing Agreement

Total Lower Basin Shortage (af)	Distribution of Shortage per Arizona-Nevada Shortage Sharing Agreement (af)		Distribution of Shortages per Modeling Assumptions (af)	
	Arizona Share	Nevada Share	Arizona Share[1]	Nevada Share[2]
400,000	320,000	13,000	320,000	13,333
500,000	400,000	17,000	400,000	16,667
600,000	480,000	20,000	480,000	20,000

1. *The allocation of Arizona's share of a shortage is calculated in the model by multiplying the total Lower Basin shortage amount by 80 percent.*
2. *The allocation of Nevada's share of a shortage is calculated in the model by multiplying the total Lower Basin shortage amount by 3.333333 percent.*

4.2.8 Modeling Assumptions Specific to Alternatives

Each alternative includes specific assumptions with regard to the four operational elements of the proposed federal action. Assumptions with regard to Shortage Guidelines, Coordinated Reservoir Operations, and the ISG were presented in Chapter 2 and are detailed in Appendix A. Assumptions with regard to the Storage and Delivery of Conserved Water element are detailed in Appendix M.

4.3 Hydrologic Resources

This section identifies the potential effects on hydrologic resources that may occur as a result of implementing the No Action Alternative and the action alternatives.

4.3.1 Methodology

The methodology and the CRSS model used to analyze the potential impacts of the alternatives to reservoir storage, reservoir releases, and the corresponding changes in river flows downstream of the reservoirs are described in Section 4.2 and Appendix A.

The CRSS model is a monthly time-step model and its output for simulated water system conditions, such as reservoir elevations or releases, can be provided on monthly and annual bases. The data and output used in the impact analysis may vary depending on the specific issue being addressed. An example of how specific months are considered to represent certain issues or conditions in the analyses follows:

Lake Powell:

- **March:** representative of months (or period) with seasonal low Lake Powell elevations;
- **July:** representative of months (or period) with seasonal high Lake Powell concentration of visitors; and
- **September:** month representing End-of-Water Year, used for water accounting and reporting in Upper Basin.

Lake Mead:

- **July:** representative of months (or period) with seasonal low Lake Mead elevations; and
- **December:** month representing End-of-Calendar Year, used for water accounting and reporting in Lower Basin.

The specific data and output used in the different resource analyses are presented in this section.

4.3.1.1 Methodology Used To Estimate a Range of Daily Glen Canyon Dam Releases

The observed CRSS model output for individual traces for specific annual Lake Powell release volumes or volume ranges was used to estimate the monthly volumes that would likely be seen under water year release volumes that were less than, equal to, and greater than 8.23 maf. These annual release volumes consisted of 7.00, 7.48, 7.80, 8.23, 9.00, 9.50, 9.50 to 11.0, and 11.0 to 16 mafy, corresponding to the Glen Canyon Dam release volumes observed under the modeled alternatives. For each month corresponding to each of these annual flow volumes, the average, maximum, and minimum daily flow volumes were then calculated using the allowable daily fluctuation parameters specified in the 1996 Glen Canyon ROD. It is recognized that monthly and daily flow patterns observed in the different release years could potentially deviate somewhat from the flow values and patterns calculated using this approach although they would most likely be very close to the calculated value. It is also noted that the release patterns for the 7.0 maf release are not as consistent because the monthly volumes would be affected by balancing of Lake Powell and Lake Mead storage. When balancing takes place, monthly release volumes shift as forecast inflow shifts, resulting in more than one possible pattern for the 7.0 maf release years.

4.3.1.2 Methodology Used To Estimate Evaporation Loss from Lake Powell and Lake Mead

Evaporation at Lake Powell and Lake Mead is simulated in CRSS by multiplying the monthly average reservoir surface area by monthly evaporation coefficients. A description of the methodology and the monthly evaporation coefficients is provided in Appendix A. A comparison of the mean and median evaporation volumes for Lake Powell and Lake Mead for the No Action Alternative and the action alternatives is provided in Appendix P.

4.3.1.3 Methodology Used To Estimate the Effect on Groundwater

The annual median elevation of the water surface in the lower Colorado River has been used as an indicator of groundwater elevations adjacent to the Colorado River within the potentially affected river reaches. This is due to the slow movement of groundwater and the time required for the decline in the groundwater table to stabilize at a decline equal to that of the river (Reclamation 2004a, Appendix J and Appendix K). The methodology used to analyze the potential effects to groundwater followed the methodology established in the LCR MSCP analysis.

4.3.2 Lake Powell and Glen Canyon Dam

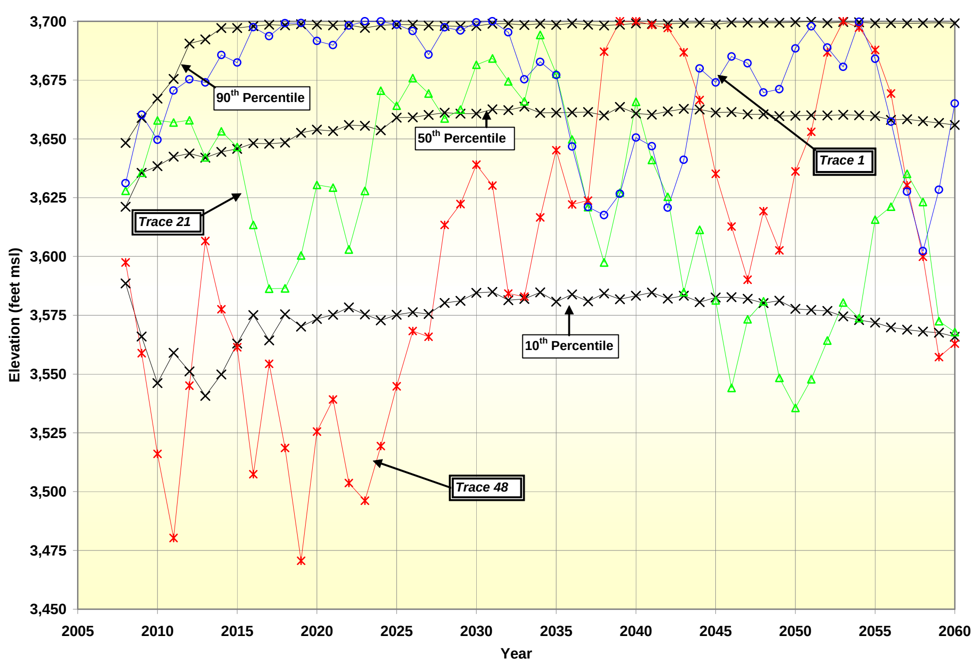
Future elevations of Lake Powell are expected to be within the range of historic water levels (Section 3.3). However, each action alternative may alter the probability (when compared to the No Action Alternative) that the reservoir may be at a given elevation in the future.

Under the No Action Alternative, the elevation of Lake Powell is projected to fluctuate between full and lower levels during the period of analysis (2008 through 2060). Figure 4.3-1 illustrates the range of reservoir elevations by three plots, labeled 90th percentile, 50th percentile and 10th percentile. The 50th percentile plot shows the modeled median elevation for each future year. The median elevation gradually increases from about 3,620 feet msl to about 3,655 feet msl in the year 2060. The 10th percentile plot shows the elevations that would be exceeded 90 percent of the time for each future year. The 10th percentile lake elevation would gradually decline from about 3,590 feet msl to about 3,565 feet msl in the year 2060.

Lake Powell elevations depicted in Figure 4.3-1 (and in Figure 4.3-2) are for modeled lake elevations at the end of July. Lake Powell elevation generally reaches its seasonal high in July whereas the seasonal low generally occurs in March.

Three distinct traces were added to Figure 4.3-1 to illustrate what was actually simulated under the various traces and respective hydrologic sequences and to highlight that the 90th, 50th, and 10th percentile plots do not represent actual traces, but rather the ranking of each year's data from the 100 traces for the conditions modeled. The traces also illustrate the variability among the different traces and that the reservoir elevations could temporarily decline below the 10th percentile line. Trace 1 represents the hydrologic sequence that begins in 1906. Trace 21 represents the hydrologic sequence that begins in 1926. Trace 48 represents the hydrologic sequence that begins in 1953.

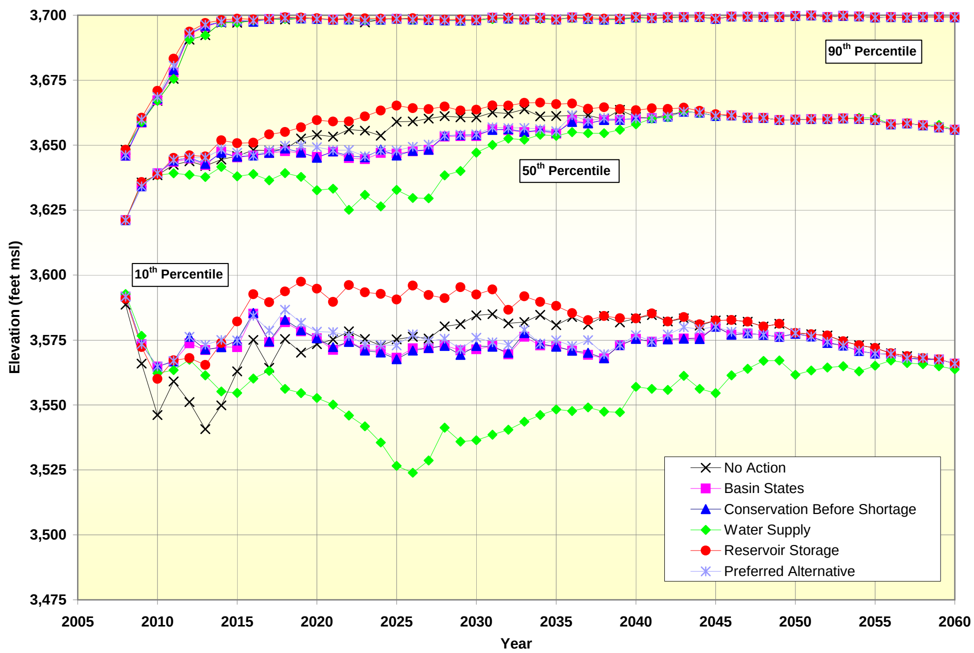
Figure 4.3-1
Lake Powell End-of-July Elevations Under the No Action Alternative
90th, 50th and 10th Percentile Values



In Figure 4.3-1, the 90th and 10th percentile lines bracket the range where 80 percent of the elevations simulated for the No Action Alternative occurred. The highs and lows shown on the three traces would likely be temporary conditions. The reservoir elevation would tend to fluctuate in the range through multi-year periods of above-average and below average inflows. Neither the timing of reservoir elevation variations, nor the length of time the elevations would remain high or low can be predicted. These events would depend on the future variation in basin runoff conditions and therefore, only projections of the likelihood of these events are possible.

Figure 4.3-2 presents a comparison of the 90th, 50th, and 10th percentile values obtained for the No Action Alternative to those of the action alternatives. This figure is best used for comparing the relative differences in the general lake elevation trends that result from the simulation of the different alternatives.

Figure 4.3-2
Lake Powell End-of-July Elevations
Comparison of Action Alternatives to No Action Alternative
90th, 50th, and 10th Percentile Values



As illustrated in Figure 4.3-2, the 90th percentile results were nearly identical for all of the alternatives. For the 50th and the 10th percentile results, the Reservoir Storage Alternative had the highest Lake Powell elevations and the Water Supply Alternative had the lowest elevations. Reservoir elevations under the Basin States and the Conservation Before Shortage alternatives, and the Preferred Alternative were similar and were generally lower than those under the No Action Alternative.

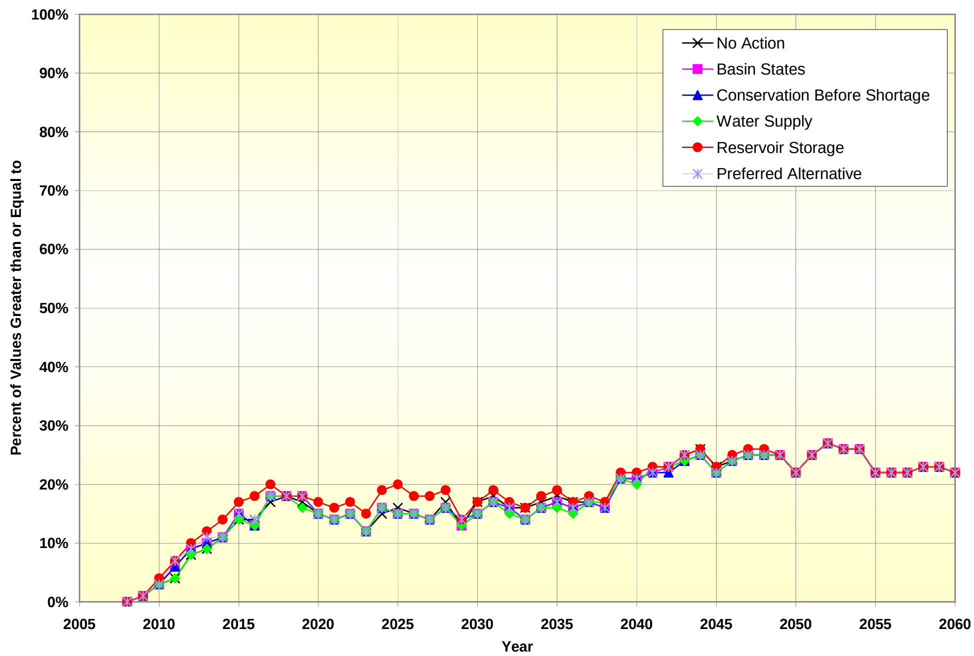
Table 4.3-1 provides a summary of the data illustrated in Figure 4.3-2, which is the 90th percentile, median (50th percentile), and 10th percentile values of the action alternatives compared to those of the No Action Alternative. The values presented in this table include those for 2026 and 2060 only. Results for the 90th percentile show that Lake Powell elevations under the action alternatives were almost the same as those under the No Action Alternative. For the 50th percentile, lake elevations under the Water Supply, Basin States, and the Conservation Before Shortage alternatives, and the Preferred Alternative were lower than those under the No Action Alternative during 2026, but were almost the same by 2060. The 10th percentile trend was very similar to the 50th percentile trend.

Table 4.3-1
Lake Powell End-of-July Elevations (feet msl)
Comparison of Action Alternatives to No Action Alternative
90th, 50th, and 10th Percentile Values

Alternative	Year 2026			Year 2060		
	90th Percentile	50th Percentile	10th Percentile	90th Percentile	50th Percentile	10th Percentile
No Action	3,698.52	3,659.17	3,576.25	3,699.21	3,655.92	3,565.89
Basin States	3,698.29	3,647.56	3,571.83	3,699.21	3,655.92	3,565.89
Conservation Before Shortage	3,698.35	3,647.79	3,570.92	3,699.21	3,655.92	3,565.89
Water Supply	3,698.31	3,629.62	3,523.95	3,699.21	3,655.87	3,563.72
Reservoir Storage	3,698.80	3,664.23	3,595.91	3,699.21	3,655.93	3,565.89
Preferred Alternative	3,698.29	3,649.33	3,577.15	3,699.21	3,655.92	3,565.89

When the Lake Powell elevation is at or exceeds 3,695 feet msl, the reservoir is considered to be essentially full. Figure 4.3-3 shows the frequency that future Lake Powell End-of-July elevations would exceed 3,695 feet msl under the No Action Alternative and the action alternatives. This type of graphical representation is best used to compare the likelihood that Lake Powell would be at or above the noted elevation (3,695 feet msl in this example) under an action alternative as compared to the No Action Alternative. Figure 4.3-3 illustrates that the percent of values that were above elevation 3,695 feet msl under the action alternatives were similar to the No Action Alternative throughout the period of analysis. The exception to this is the Reservoir Storage Alternative which provides slightly higher exceedence values than the No Action Alternative between 2010 through 2037. This means that Lake Powell elevations would generally tend to be higher under the Reservoir Storage Alternative, as compared to the No Action Alternative.

Figure 4.3-3
Lake Powell End-of-July Elevations
Comparison of Action Alternatives to No Action Alternative
Percent of Values Greater Than or Equal to Elevation 3,695 feet msl



As summarized in Table 4.3-2, the exceedence values under the Basin States, Conservation Before Shortage, and Water Supply alternatives, and the Preferred Alternative were essentially the same as those observed under the No Action Alternative in most years. The probability values under the Reservoir Storage Alternative were slightly higher than those under the No Action Alternative.

Table 4.3-2
Lake Powell End-of-July Elevations
Comparison of Action Alternatives to No Action Alternative
Percent of Values Greater Than or Equal to Elevation 3,695 feet msl

Alternatives	Year						
	2008	2016	2026	2030	2040	2050	2060
No Action	0	14	15	17	21	22	22
Basin States	0	13	15	15	21	22	22
Conservation Before Shortage	0	13	15	15	21	22	22
Water Supply	0	13	15	15	20	22	22
Reservoir Storage	0	18	18	17	22	22	22
Preferred Alternative	0	14	15	15	21	22	22

The threshold for water access to Rainbow Bridge is elevation 3,650 feet msl. Below this threshold elevation, access to Rainbow Bridge would require hiking. As shown in Figure 4.3-4, the Reservoir Storage Alternative had the lowest frequency of occurrences below this threshold, and the Water Supply Alternative had higher frequency of occurrences below elevation 3,650 feet msl relative to the No Action Alternative.

Figure 4.3-4
Lake Powell End-of-September Elevations
Comparison of Action Alternatives to No Action Alternative
Percent of Values Less Than or Equal to Elevation 3,650 feet msl

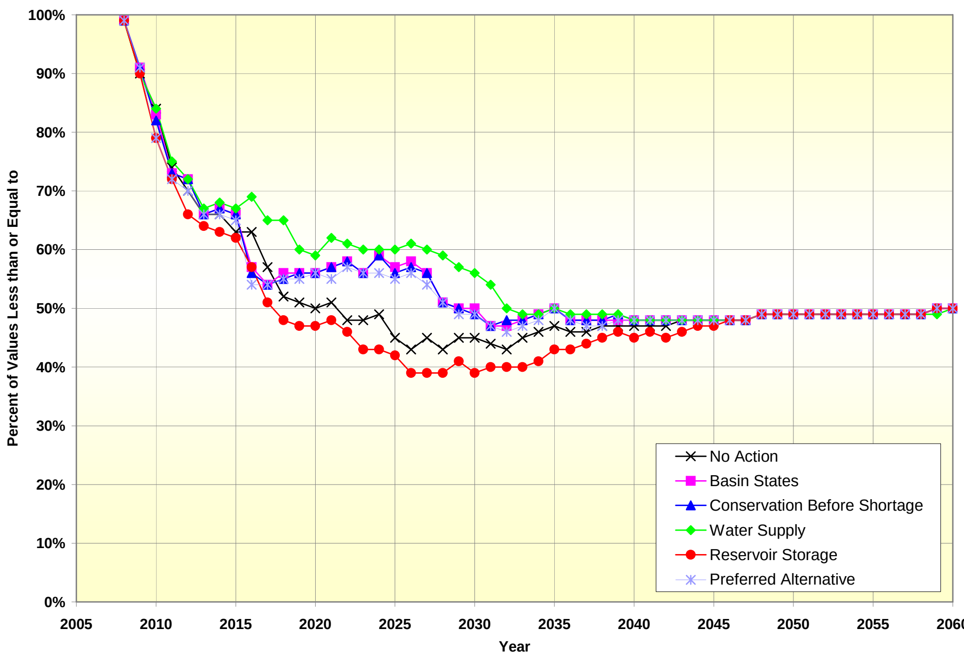


Table 4.3-3 summarizes the results shown in Figure 4.3-4 for elevation 3,650 feet msl for the No Action Alternative and the action alternatives for selected years. All alternatives were similar at the beginning and end of the modeled years, but variation did occur from about 2016 until about 2040. During that period, Lake Powell elevations under the Reservoir Storage Alternative were below elevation 3,650 feet msl less frequently than those under the No Action Alternative; the elevations under the Basin States, Conservation Before Shortage, and Water Supply alternatives, and the Preferred Alternative were below elevation 3,650 feet msl more frequently than those under the No Action Alternative.

Table 4.3-3
Lake Powell End-of-September Elevations
Comparison of Action Alternatives to No Action Alternative
Percent of Values Less Than or Equal to Elevation 3,650 feet msl

Alternatives	Year						
	2008	2016	2026	2030	2040	2050	2060
No Action	99	63	43	45	47	49	50
Basin States	99	57	58	50	48	49	50
Conservation Before Shortage	99	56	57	49	48	49	50
Water Supply	99	69	61	56	48	49	50
Reservoir Storage	99	57	39	39	45	49	50
Preferred Alternative	99	54	56	49	48	49	50

Figure 4.3-5 illustrates the results for elevations equal to or less than 3,626 feet msl. An elevation of 3,626 feet msl is the level at which there is a navigational detour at the Wahweap Marina and at Gregory Butte. As is shown on this figure, the Reservoir Storage Alternative had less impact on this threshold than the No Action Alternative. The elevations under the Water Supply, Basin States, and Conservation Before Shortage alternatives, and the Preferred Alternative, were below elevation 3,626 feet msl more frequently than those under the No Action Alternative. All alternatives were similar by about 2053.

Figure 4.3-5
Lake Powell End-of-September Elevations
Comparison of Action Alternatives to No Action Alternative
Percent of Values Less Than or Equal to Elevation 3,626 feet msl

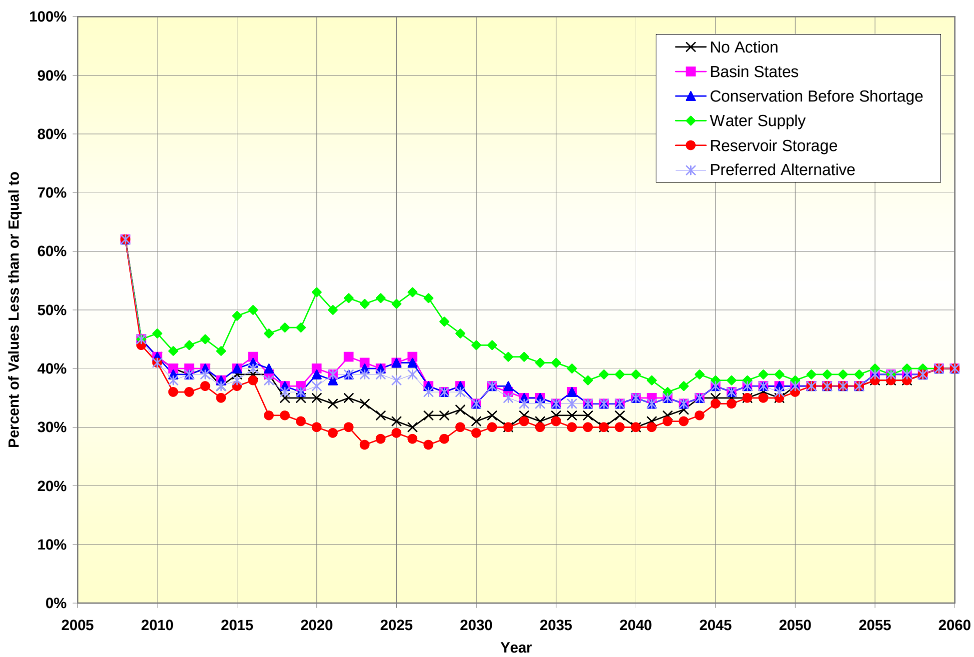


Table 4.3-4 summarizes the data illustrated in Figure 4.3-5 for elevation 3,626 feet msl. Lake Powell elevations under the Reservoir Storage Alternative were below 3,626 feet msl less frequently than those under the No Action Alternative. Lake elevations under the Water Supply, Basin States, and Conservation Before Shortage alternatives, and the Preferred Alternative, were below elevation 3,626 feet msl more frequently than those under the No Action Alternative.

Table 4.3-4
Lake Powell End-of- September Elevations
Comparison of Action Alternatives to No Action Alternative
Percent of Values Less Than or Equal to Elevation 3,626 feet msl

Alternatives	Year						
	2008	2016	2026	2030	2040	2050	2060
No Action	62	39	30	31	30	37	40
Basin States	62	42	42	34	35	37	40
Conservation Before Shortage	62	41	41	34	35	37	40
Water Supply	62	50	53	44	39	38	40
Reservoir Storage	62	38	28	29	30	36	40
Preferred Alternative	62	40	39	34	35	37	40

Figure 4.3-6 compares the percent of values less than or equal to elevation 3,620 feet msl for the No Action Alternative and the action alternatives. The Hite Marina, Hite Public Launch Ramp, and Castle Rock Cut are closed at elevation 3,620 feet msl. Lake Powell elevations under the Water Supply, Basin States, and Conservation Before Shortage alternatives, and the Preferred Alternative were below 3,620 feet msl more frequently than those under the No Action Alternative. Lake Powell elevations under the Reservoir Storage Alternative were below 3,620 feet msl less frequently than those under the No Action Alternative for most of the modeled years.

Table 4.3-5 shows that all of the action alternatives varied from the No Action Alternative from about 2016 until about 2040. During this period, most of the alternatives, including the No Action Alternative, were below 3,620 feet msl between 25 and 40 percent of the time. The exceptions were elevations under the Water Supply Alternative which were below 3,620 feet msl between 37 and 52 percent of the time and elevations under the Reservoir Storage Alternative which were below 3,620 feet msl between 24 and 33 percent of the time.

Figure 4.3-6
Lake Powell End-of-September Elevations
Comparison of Action Alternatives to No Action Alternative
Percent of Values Less Than or Equal to Elevation 3,620 feet msl

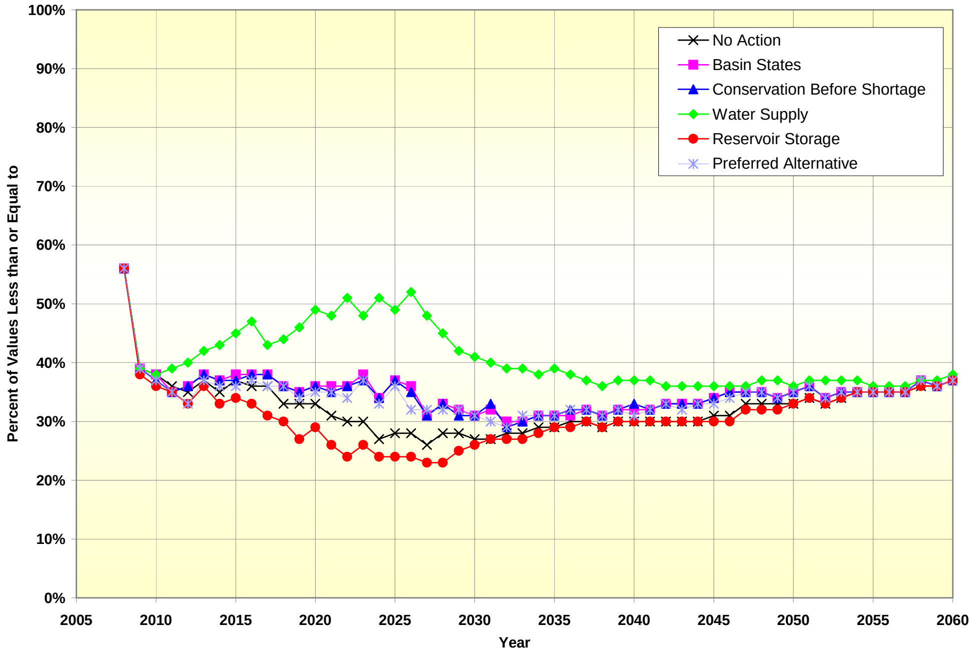


Table 4.3-5
Lake Powell End-of-September Elevations
Comparison of Action Alternatives to No Action Alternative
Percent of Values Less Than or Equal to Elevation 3,620 feet msl

Alternatives	Year						
	2008	2016	2026	2030	2040	2050	2060
No Action	56	36	28	27	30	35	37
Basin States	56	38	36	31	32	35	37
Conservation Before Shortage	56	38	35	31	33	35	37
Water Supply	56	47	52	41	37	36	38
Reservoir Storage	56	33	24	26	30	33	37
Preferred Alternative	56	37	32	31	31	35	37

Figure 4.3-7 compares the percent of values less than or equal to elevation 3,588 feet msl for the No Action Alternative and the action alternatives. When Lake Powell elevations are below 3,588 feet msl, the Antelope Point Public Launch Ramp is closed. Lake elevations under the Reservoir Storage Alternative were below 3,588 feet msl less frequently than those under the No Action Alternative for most of the modeled years. Lake elevations under the Water Supply, Basin States, and Conservation Before Shortage alternatives, and the Preferred Alternative were below 3,588 feet msl more frequently than those under the No Action Alternative.

Figure 4.3-7
Lake Powell End-of-September Elevations
Comparison of Action Alternatives to No Action Alternative
Percent of Values Less Than or Equal to Elevation 3,588 feet msl

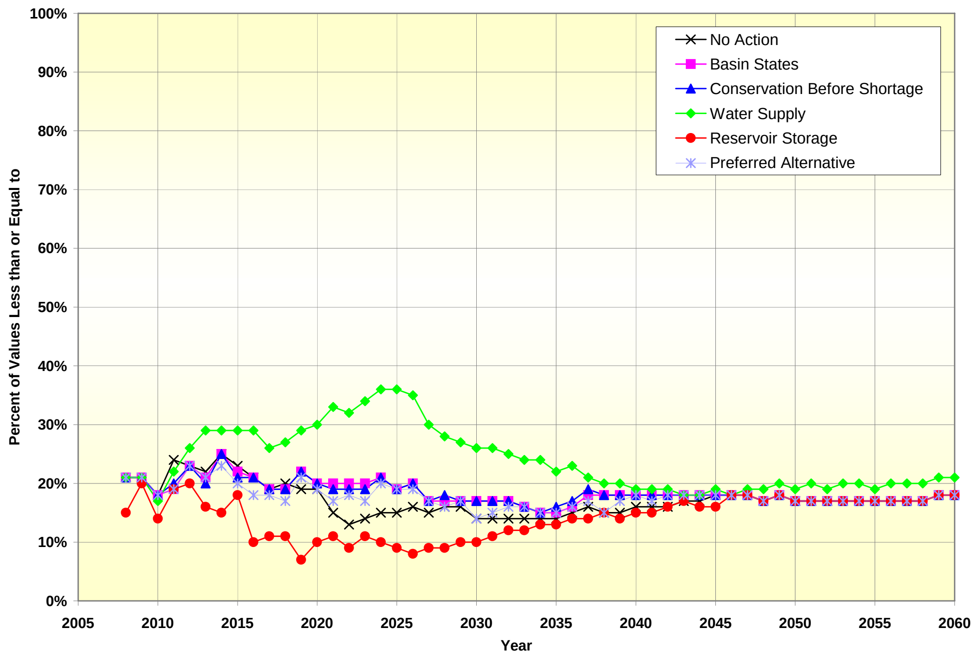


Table 4.3-6 provides a summary of the data illustrated in Figure 4.3-7 for an elevation of 3,588 feet msl. In general, lake elevations for all alternatives were below 3,588 feet msl between 14 and 21 percent of the time. The exceptions are the elevations under the Water Supply Alternative which were below 3,588 feet msl between 19 and 35 percent of the time and elevations under the Reservoir Storage Alternative which were below 3,588 feet msl between 8 and 18 percent of the time.

Table 4.3-6
Lake Powell End-of-September Elevations
Comparison of Action Alternatives to No Action Alternative
Percent of Values Less Than or Equal to Elevation 3,588 feet msl

Alternatives	Year						
	2008	2016	2026	2030	2040	2050	2060
No Action	21	21	16	14	16	17	18
Basin States	21	21	20	17	18	17	18
Conservation Before Shortage	21	21	20	17	18	17	18
Water Supply	21	29	35	26	19	19	21
Reservoir Storage	15	10	8	10	15	17	18
Preferred Alternative	21	18	19	14	18	17	18

Figure 4.3-8 compares the percent of values less than or equal to elevation 3,560 feet msl for the No Action Alternative and the action alternatives. Below an elevation of 3,560 feet msl, the Wahweap and Stateline Public Launch Ramps, the Bullfrog Low Water Alternative Launch Ramp, and the Halls Crossing Public Launch Ramps are closed. Results indicate that for most alternatives, the Lake Powell end-of-September elevations were lower than 3,560 feet msl between zero and 15 percent of the time, with the exception of the Water Supply Alternative. Lake elevations under the Water Supply Alternative were below 3,560 feet msl as much as 23 percent of the time.

Figure 4.3-8
Lake Powell End-of-September Elevations
Comparison of Action Alternatives to No Action Alternative
Percent of Values Less Than or Equal to Elevation 3,560 feet msl

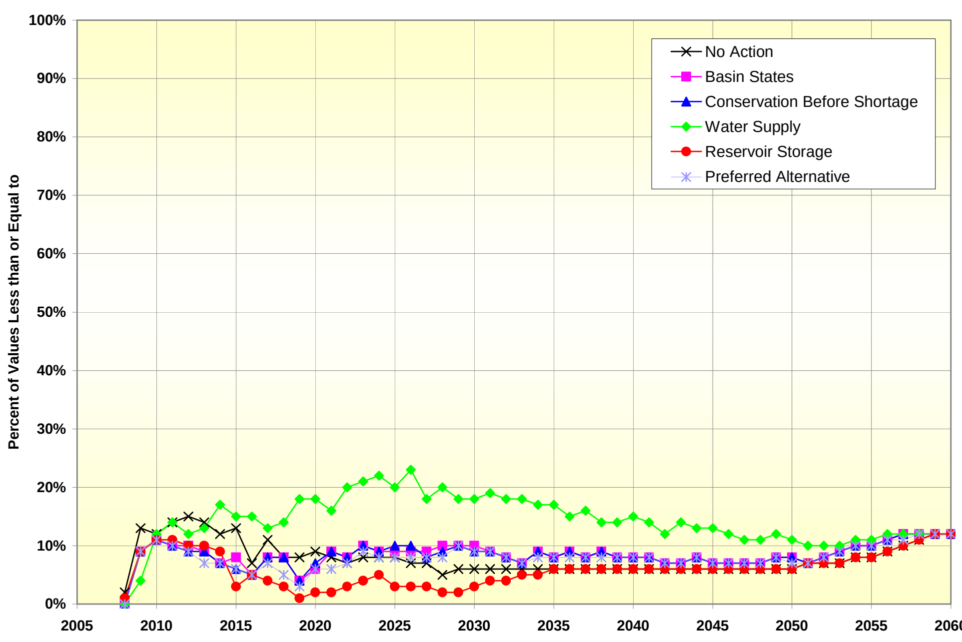


Table 4.3-7 provides a summary of the data illustrated in Figure 4.3-8 for elevation 3,560 feet msl. Lake Powell elevations under the Water Supply Alternative were below 3,560 feet msl more frequently than those under the No Action Alternative. Elevations under the Reservoir Storage Alternative were below 3,560 feet msl less frequently than those under the No Action Alternative.

Table 4.3-7
Lake Powell End-of- September Elevations
Comparison of Action Alternatives to No Action Alternative
Percent of Values Less Than or Equal to Elevation 3,560 feet msl

Alternative	Year						
	2008	2016	2026	2030	2040	2050	2060
No Action	2	7	7	6	6	6	12
Basin States	0	5	9	10	8	8	12
Conservation Before Shortage	0	5	10	9	8	8	12
Water Supply	0	15	23	18	15	11	12
Reservoir Storage	1	5	3	3	6	6	12
Preferred Alternative	0	5	8	9	8	7	12

Figure 4.3-9 compares the percent of values equal to or less than elevation 3,555 feet msl for the No Action Alternative and the action alternatives. Below an elevation of 3,555 feet msl, the Wahweap, Antelope Point, Bullfrog, and Halls Crossing marinas are closed. Results indicate that for most alternatives, the Lake Powell end-of-September elevations were lower than 3,555 feet msl between zero and 12 percent of the time. The exceptions are the elevations under the Water Supply Alternative which were lower than 3,555 feet msl up to 23 percent of the time.

Figure 4.3-9
Lake Powell End-of-September Elevations
Comparison of Action Alternatives to No Action Alternative
Percent of Values Less Than or Equal to Elevation 3,555 feet msl

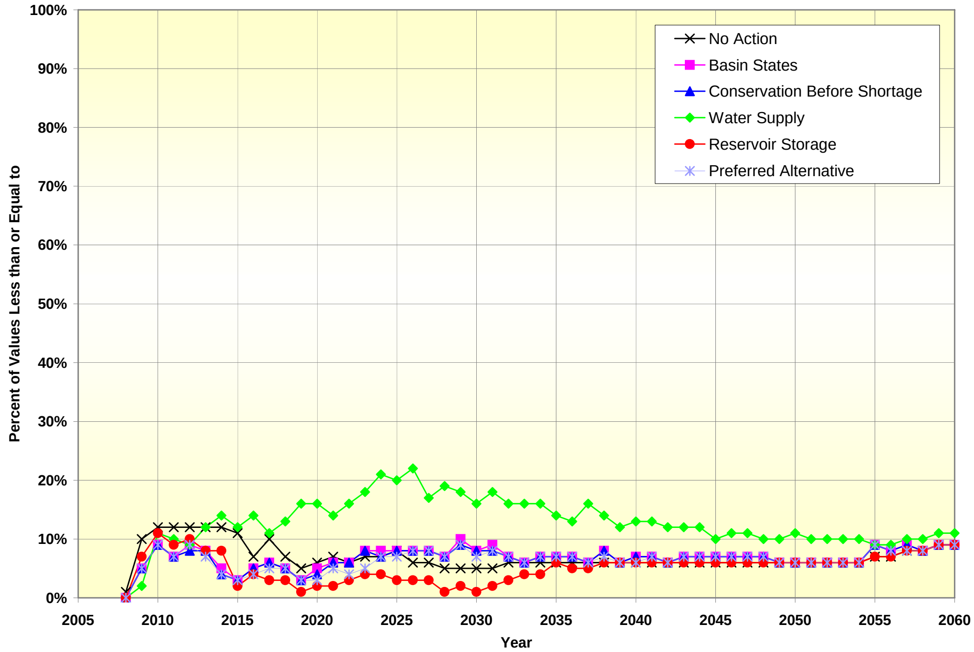


Table 4.3-8 provides a summary of the data illustrated in Figure 4.3-9 for elevation 3,555 feet msl. Lake Powell elevations under the Water Supply Alternative were below 3,555 feet msl more frequently than those under the No Action Alternative. Elevations under the Reservoir Storage Alternative were below 3,555 feet msl less frequently than those under the No Action Alternative through year 2035 and thereafter, the values were similar.

Table 4.3-8
Lake Powell End-of-September Elevations
Comparison of Action Alternatives to No Action Alternative
Percent of Values Less Than or Equal to Elevation 3,555 feet msl

Alternative	Year						
	2008	2016	2026	2030	2040	2050	2060
No Action	1	7	6	5	6	6	9
Basin States	0	5	8	8	7	6	9
Conservation Before Shortage	0	5	8	8	7	6	9
Water Supply	0	14	22	16	13	11	11
Reservoir Storage	0	4	3	1	6	6	9
Preferred Alternative	0	4	8	7	6	6	9

Figure 4.3-10 compares the percent of values equal to or less than 3,550 feet msl projected under the No Action Alternative and the action alternatives. Below this elevation, the operation of the John Atlantic Burr Ferry may be affected. The Lake Powell end-of-September elevations under the alternatives were lower than 3,550 feet msl infrequently, ranging between zero and 12 percent. The exception to this was the Water Supply Alternative, which had elevations that were below 3,550 feet msl up to 20 percent of the time. Elevations under the Reservoir Storage, Basin States, and Conservation Before Shortage alternatives, and the Preferred Alternative, were all very similar to those under the No Action Alternative throughout the period of analysis.

Figure 4.3-10
Lake Powell End-of-September Elevations
Comparison of Action Alternatives to No Action Alternative
Percent of Values Less Than or Equal to Elevation 3,550 feet msl

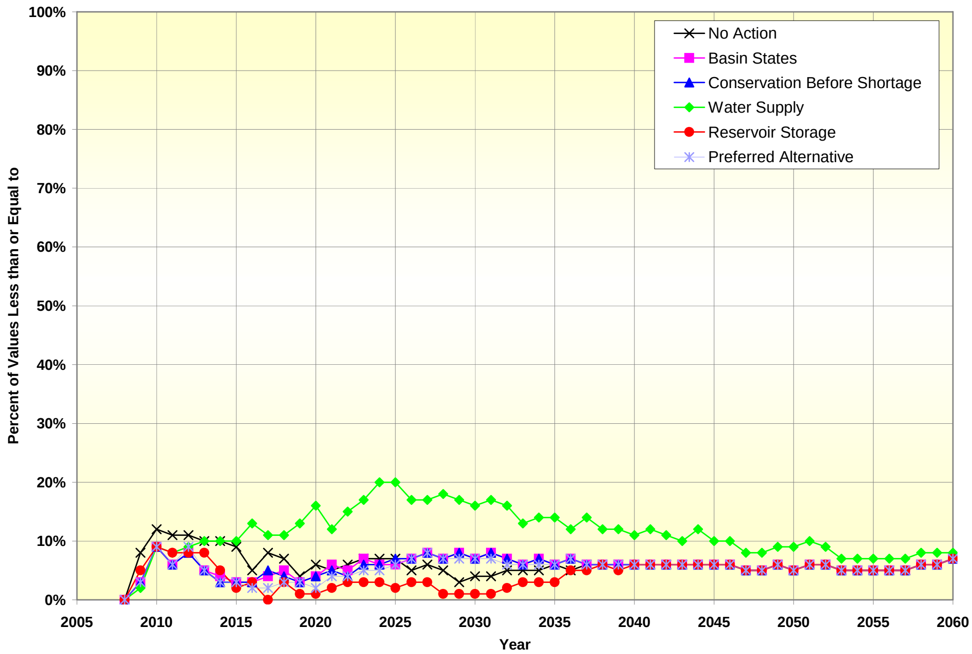


Table 4.3-9 provides a summary of the data illustrated in Figure 4.3-10 and shows that Lake Powell elevations under the Basin States, Conservation Before Shortage, and Reservoir Storage alternatives, and the Preferred Alternative, were generally within the same range of those observed under the No Action Alternative. Elevations under the Water Supply Alternative were below 3,550 feet msl more frequently compared to the other alternatives.

Table 4.3-9
Lake Powell End-of-September Elevations
Comparison of Action Alternatives to No Action Alternative
Percent of Values Less Than or Equal to Elevation 3,550 feet msl

Alternatives	Year						
	2008	2016	2026	2030	2040	2050	2060
No Action	0	5	5	4	6	5	7
Basin States	0	3	7	7	6	5	7
Conservation Before Shortage	0	3	7	7	6	5	7
Water Supply	0	13	17	16	11	9	8
Reservoir Storage	0	3	3	1	6	5	7
Preferred Alternative	0	2	7	7	6	5	7

Figure 4.3-11 compares the percent of values for Lake Powell end-of-March elevations that were less than or equal to 3,490 feet msl, the minimum power pool for efficient electrical generation at the Glen Canyon Powerplant, between the No Action Alternative and the action alternatives. Lake Powell generally reaches its seasonal low water elevation in March. Figure 4.3-11 shows that Lake Powell end-of-March elevation were below 3,490 feet msl infrequently under the No Action, Basin States, Conservation Before Shortage, and Reservoir Storage alternatives, and the Preferred Alternative. Lake Powell end-of-March elevations under the Water Supply Alternative were below 3,490 feet msl more frequently than those under the No Action Alternative, with the differences up to eight percent.

Figure 4.3-11
Lake Powell End-of-March Elevations
Comparison of Action Alternatives to No Action Alternative
Percent of Values Less Than or Equal to Elevation 3,490 feet msl

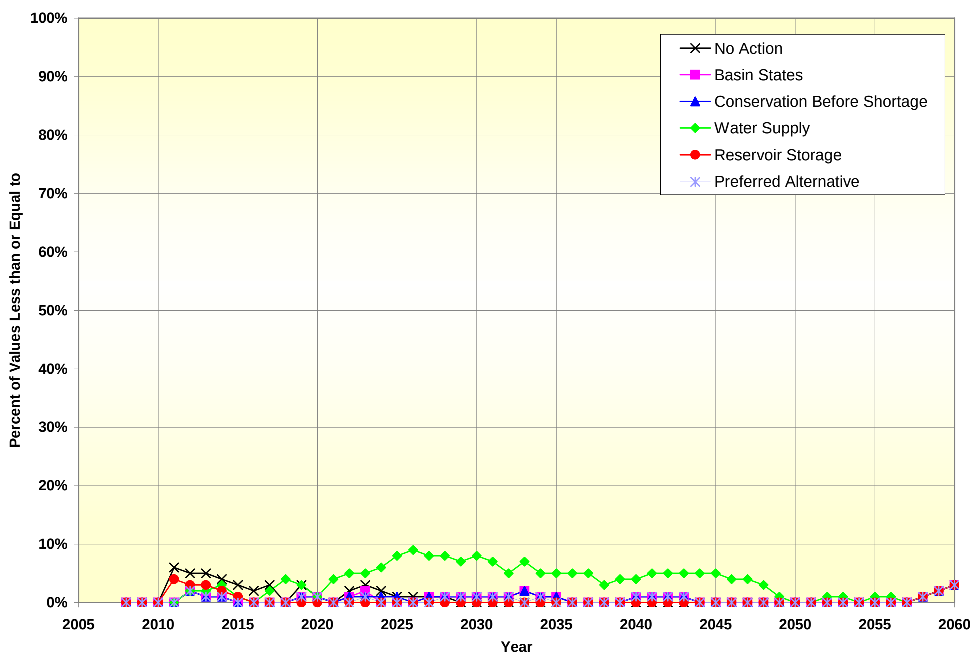


Table 4.3-10 provides a summary of the data illustrated in Figure 4.3-11 for elevation 3,490 feet msl. As presented in this table, elevations under all alternatives, with the exception of the Water Supply Alternative, were below 3,490 feet msl no more than three percent of the time in the years displayed.

Table 4.3-10
Lake Powell End-of-March Elevations
Comparison of Action Alternatives to No Action Alternative
Percent of Values Less Than or Equal to Elevation 3,490 feet msl

Alternatives	Year						
	2008	2016	2026	2030	2040	2050	2060
No Action	0	2	1	0	0	0	3
Basin States	0	0	0	1	1	0	3
Conservation Before Shortage	0	0	0	1	1	0	3
Water Supply	0	0	9	8	4	0	3
Reservoir Storage	0	0	0	0	0	0	3
Preferred Alternative	0	0	0	1	1	0	3

4.3.3 Glen Canyon Dam to Lake Mead

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 three percent of the total flow, are concentrated over very short periods of time, and will not be affected by the proposed federal action. However, future annual and the monthly distribution of releases from Glen Canyon Dam may be affected by the proposed federal action (Section 3.3).

Table 4.3-11 provides a comparison of the relative frequency of occurrence of different annual release volumes from Glen Canyon Dam under the No Action Alternative and the action alternatives for the period 2008 through 2026. Table 4.3-12 provides a similar comparison for the period 2008 through 2060. The reported values are water year values. Releases greater than 9.5 maf generally correspond to years where either equalization or spill avoidance releases are made from Glen Canyon Dam.

Table 4.3-11
Glen Canyon Dam Annual Water Releases
Probability of Occurrence of Different Release Volumes (percent)
Comparison of Action Alternatives to No Action Alternative
Water Years 2008 through 2026

Glen Canyon Dam Release Volumes	Alternative					
	No Action	Basin States	Conservation Before Shortage	Water Supply	Reservoir Storage	Preferred Alternative
Greater than 16.00 maf	3.63	3.26	3.32	2.89	3.74	3.53
Between 11.01 to 16.00 maf	17.11	16.79	16.89	17.26	16.84	16.42
Between 9.01 to 11.00 maf	14.05	13.53	13.42	38.95	15.74	14.37
Between 8.51 to 9.00 maf	4.42	26.00	25.37	6.05	4.21	22.37
Between 8.24 to 8.50 maf	2.74	2.37	2.47	3.68	3.21	2.11
Minimum Objective Release of 8.23 maf	57.74	27.79	28.42	21.37	38.95	31.16
Between 7.51 to 8.22 maf	0.21	0.95	0.79	3.95	17.32	0.68
Between 7.01 to 7.50 maf	0.05	8.32	8.26	4.32	0.00	8.11
Less than or equal to 7.00 maf	0.05	1.00	1.05	1.53	0.00	1.26
Total	100.00	100.00	100.00	100.00	100.00	100.00

Table 4.3-12
Glen Canyon Dam Annual Water Releases
Probability of Occurrence of Different Release Volumes (percent)
Comparison of Action Alternatives to No Action Alternative
Water Years 2008 through 2060

Glen Canyon Dam Release Volumes	Alternative					
	No Action	Basin States	Conservation Before Shortage	Water Supply	Reservoir Storage	Preferred Alternative
Greater than 16.00 maf	4.00	3.83	3.85	3.19	4.04	3.96
Between 11.01 to 16.00 maf	14.08	13.85	13.92	14.49	14.40	13.72
Between 9.01 to 11.00 maf	12.81	12.36	12.28	20.91	13.08	12.66
Between 8.51 to 9.00 maf	3.72	11.53	11.30	4.30	3.68	10.19
Between 8.24 to 8.50 maf	2.25	2.08	2.11	2.77	2.36	2.00
Minimum Objective Release of 8.23 maf	63.04	52.68	52.91	50.68	56.25	53.87
Between 7.51 to 8.22 maf	0.08	0.34	0.28	1.57	6.21	0.25
Between 7.01 to 7.50 maf	0.02	2.98	2.96	1.55	0.00	2.91
Less than or equal to 7.00 maf	0.02	0.36	0.38	0.55	0.00	0.45
Total	100.00	100.00	100.00	100.00	100.00	100.00

As is shown in Table 4.3-11, during the interim period (2008 through 2026), the most frequently occurring releases under the No Action Alternative are 8.23 maf, occurring approximately 58 percent of the time. The frequency of releases equal to the annual minimum objective release of 8.23 maf under the action alternatives ranged from approximately 21 to 39 percent. Releases less than the annual minimum objective release of 8.23 maf occurred less than one percent of the time under the No Action Alternative, approximately 10 percent under the Basin States, Conservation Before Shortage, and Water Supply alternatives, and the Preferred Alternative, and approximately 17 percent under the Reservoir Storage Alternative. Releases greater than the annual minimum objective release of 8.23 maf occurred approximately 42 percent under the No Action Alternative, approximately 62 percent under the Basin States and Conservation Before Shortage alternatives, approximately 69 percent under the Water Supply Alternative, approximately 59 percent under the Preferred Alternative, and approximately 44 percent under the Reservoir Storage Alternative.

The distribution of the modeled annual Glen Canyon Dam releases is different if the values for the entire period of analysis are considered as compared to those during the interim period. As is shown in Table 4.3-12, during the entire period (2008 through 2060), the most frequently occurring releases for all alternatives are 8.23 maf, primarily due to the assumption that operations under all action alternatives revert to those of the No Action Alternative after 2026. Releases equal to the annual minimum objective release of 8.23 maf occurred approximately 63 percent under the No Action Alternative, approximately 53 percent under the Basin States, and Conservation Before Shortage alternatives, and the Preferred Alternative, approximately 51 percent under the Water Supply Alternative, and approximately 56 percent under the Reservoir Storage Alternative. Releases less than the annual minimum objective release of 8.23 maf occurred less than one percent of the time under the No Action Alternative, approximately four percent under the Basin States, Conservation Before Shortage, and Water Supply alternatives, and the Preferred Alternative, and approximately six percent under the Reservoir Storage Alternative.

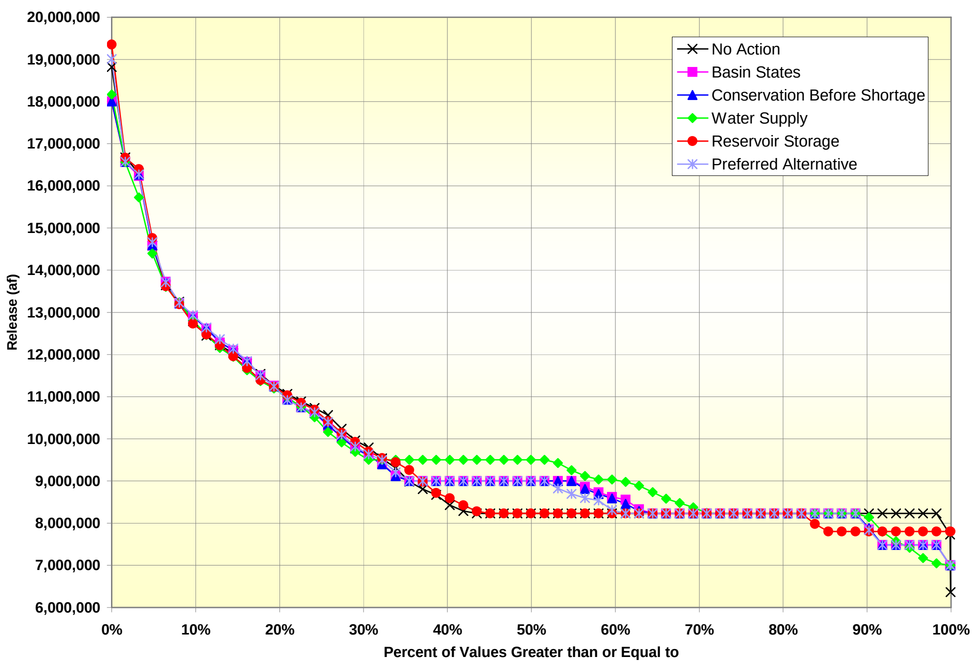
Figure 4.3-12 presents a comparison of the 90th, 50th, and 10th percentile values of the Glen Canyon Dam water year releases observed under the action alternatives to those under the No Action Alternative. As illustrated in Figure 4.3-12, the 90th percentile values under all of the alternatives fluctuate and range between 11.0 mafy to about 13.4 mafy, primarily due to spill avoidance releases. For the 50th percentile values, the Reservoir Storage Alternative and the No Action Alternative are nearly identical, with consistent releases of 8.23 maf. The Basin States and Conservation Before Shortage alternatives, and the Preferred Alternative show releases greater than the minimum objective release of 8.23 maf, a result of balancing with a 9.0 maf maximum release constraint. The Water Supply Alternative shows releases greater than the minimum objective release of 8.23 maf due to balancing with a 9.5 maf maximum release constraint.

Figure 4.3-12
Glen Canyon Dam Water Year Releases
Comparison of Action Alternatives to No Action Alternative
90th, 50th, and 10th Percentile Values

The 10th percentile values showed that the Water Supply Alternative provided lower releases than the No Action Alternative from 2009 and 2015, and thereafter, were similar to those observed under the No Action Alternative. The Basin States and Conservation Before Shortage alternatives, and the Preferred Alternative also provided lower annual release volumes than the No Action Alternative from 2009 through 2015. The 10th percentile values for releases under the Reservoir Storage Alternative are below those of the No Action Alternative through 2026.

Figure 4.3-13 illustrates the cumulative distribution of the Glen Canyon Dam water year releases under the No Action Alternative and the action alternatives for the interim period (2008 through 2026). This figure provides a means for comparing the frequency that the minimum objective release of 8.23 maf is made under the different alternatives as well as identifying the frequency and magnitude of Glen Canyon Dam releases above and below the minimum objective release of 8.23 maf. As illustrated in Figure 4.3-13, the minimum objective release of 8.23 maf under the No Action Alternative is met or exceeded approximately 98 percent or more of the time. The minimum objective release of 8.23 maf under the action alternatives is met or exceeded approximately 86 percent or more of the time. The exception to this is the Reservoir Storage Alternative under which the minimum objective release of 8.23 maf is met or exceeded approximately 82 percent of the time.

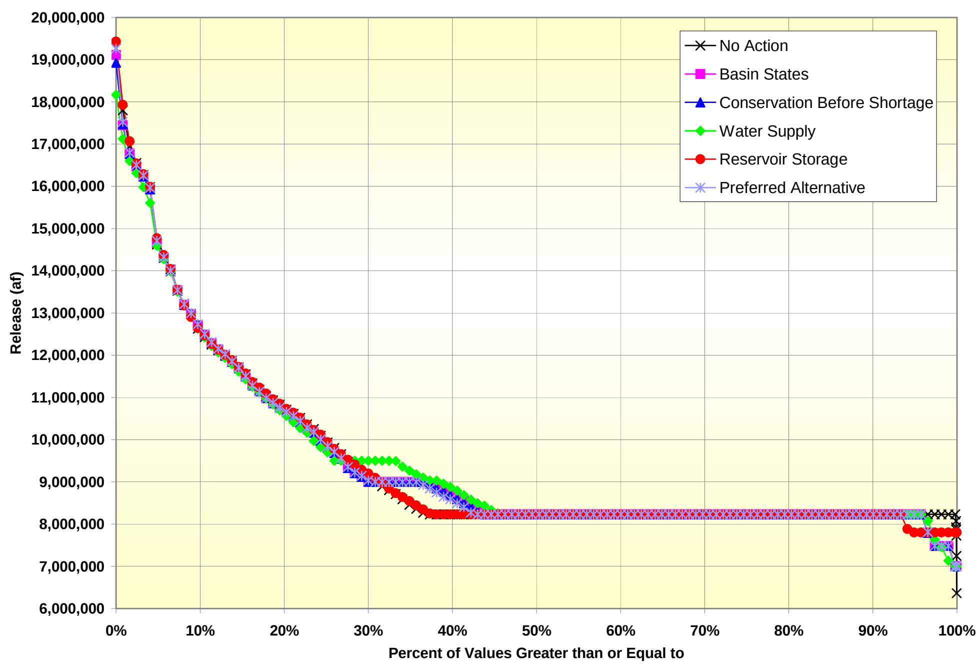
Figure 4.3-13
Glen Canyon Dam Water Year Releases
Comparison of Action Alternatives to No Action Alternative
Water Years 2008 through 2026



The minimum observed release volume of 6.36 maf occurs under the No Action Alternative. Unlike the action alternatives, the No Action Alternative does not include a range of elevations where annual releases less than 8.23 maf are permitted. A release of less than 8.23 maf can only occur under the No Action Alternative due to physical release constraints at Lake Powell (approximately elevation 3,460 feet msl). Appendix B, Section B.2 describes this physical release constraint in more detail. By providing for releases less than 8.23 maf (as low as 7.0 maf), the action alternatives avoid reaching elevations where releases are physically constrained. The minimum observed water year release volume under the Preferred Alternative and the Basin States, Conservation Before Shortage, and Water Supply alternatives is 7.0 maf. The minimum observed water year release volume under the Reservoir Storage Alternative is 7.8 maf.

Figure 4.3-14 illustrates the cumulative distribution of the Glen Canyon Dam water year releases under the No Action Alternative and the action alternatives for the modeling period 2008 through 2060. As illustrated in Figure 4.3-14, the minimum objective release of 8.23 maf in the alternatives is met or exceeded 96 percent or more of the time. The exception to this is the Reservoir Storage Alternative under which the minimum objective release of 8.23 maf is met or exceeded approximately 93 percent of the time. The minimum releases observed during the interim period in Figure 4.3-13 are also observed in Figure 4.3-14, which reflects the overlap in the modeling period covered for these analyses.

Figure 4.3-14
Glen Canyon Dam Water Year Releases
Comparison of Action Alternatives to No Action Alternative
Water Years 2008 through 2060



4.3.3.1 Effect of Glen Canyon Dam Annual Releases on Daily River Flows Below Glen Canyon Dam

Table 4.3-11 and Figure 4.3-13 compare the probabilities of occurrence of different Glen Canyon Dam annual release volumes for each alternative relative to the No Action Alternative. Relatively small differences are seen at the higher releases (above 9.5 maf) that are primarily a result of equalization and spill avoidance releases. The majority of differences are due to operations under each action alternative that deviate from the minimum objective release of 8.23 maf – when releases are being made to balance Lake Powell and Lake Mead contents and when Glen Canyon Dam releases are constrained to specific values other than 8.23 maf.

Changes in the annual release volume will likely result in changes to the monthly distribution of releases. Furthermore, even though future daily and hourly releases are expected to continue to be made according to the parameters of the 1996 Glen Canyon Dam ROD (Section 3.3.2), changes in monthly releases may result in different distributions of daily and hourly releases.

To assess the potential impacts of such changes, monthly release patterns were developed for a set of annual release volumes and/or ranges (7.0, 7.48, 7.8, 8.23, 9.0, 9.5, 9.5 to 11.0, and 11.0 to 16.0 maf). The monthly release patterns were the result of an analysis of the monthly modeled releases and are considered to be representative of all of the alternatives. Based on the monthly release patterns, the 1996 Glen Canyon Dam ROD parameters were applied to determine the average, minimum, and maximum daily releases for each month and each annual release volume (Tables 4.3-13, Table 4.3-14, and Table 4.3-15 respectively). These data show the correlation between annual release volumes and the likely daily and hourly flows; however, actual daily and hourly flows will be the result of decisions based on actual operating conditions and other factors considered in real-time.

The information in Tables 4.3-13, Table 4.3-14, and Table 4.3-15 may be coupled with the information in Table 4.3-11 to determine the probability of occurrence for each alternative of specific minimum, maximum, and average daily flows for specific months. This information can then be used to evaluate potential downstream impacts to water quality and other environmental resources.

Table 4.3-13
Average Daily Glen Canyon Dam Releases (cfs)
Corresponding to Various Annual Release Volumes

	7.0 maf[1]	7.48 maf	7.8 maf	8.23 maf	9.0 maf	9.5 maf	9.5 to 11.0 maf	11.0 to 16.0 maf
Oct	9,758	7,806	9,758	9,758	9,758	9,758	10,775	11,518
Nov	10,083	8,403	10,083	10,083	10,083	10,083	11,048	11,806
Dec	13,011	9,758	9,758	13,011	13,011	13,011	14,309	15,094
Jan	10,759	13,011	13,011	13,011	13,011	13,824	15,286	16,654
Feb	9,724	10,804	10,804	10,804	11,704	11,704	14,722	17,347
Mar	7,319	9,758	9,758	9,758	10,571	10,571	12,376	14,634
Apr	7,563	8,403	10,083	10,083	10,083	10,924	12,127	15,226
May	7,319	9,758	9,758	9,758	10,571	13,011	11,523	15,449
Jun	9,076	10,083	10,083	10,924	13,444	15,125	14,485	22,385
Jul	11,711	13,011	13,011	13,824	16,263	17,077	16,202	22,281
Aug	11,711	13,011	13,011	14,637	17,077	17,890	19,201	24,355
Sep	7,866	10,083	10,083	10,588	13,444	14,285	17,780	22,563

1. The analysis showed that a consistent monthly release pattern was not evident for 7.0 maf annual release years, primarily due to the variability in forecasted inflows. The monthly pattern shown was taken from a representative trace (Trace 89 for WY 2017 from the Water Supply Alternative)

Table 4.3-14
Minimum Hourly Glen Canyon Dam Releases (cfs)
Corresponding to Various Annual Release Volumes

	7.0 maf[1]	7.48 maf	7.8 maf	8.23 maf	9.0 maf	9.5 maf	9.5 to 11.0 maf	11.0 to 16.0 maf
Oct	6,458	5,006	6,458	6,458	6,458	6,458	7,475	8,218
Nov	6,783	5,603	6,783	6,783	6,783	6,783	7,748	8,506
Dec	8,711	6,458	6,458	8,711	8,711	8,711	10,009	10,794
Jan	7,459	8,711	8,711	8,711	8,711	9,524	10,986	12,354
Feb	6,924	7,504	7,504	7,504	8,404	8,404	10,422	13,047
Mar	5,000	6,458	6,458	6,458	7,271	7,271	9,076	10,334
Apr	5,000	5,603	6,783	6,783	6,783	7,624	8,827	11,926
May	5,000	6,458	6,458	6,458	7,271	8,711	8,223	11,149
Jun	6,276	6,783	6,783	7,624	9,144	10,825	10,185	17,000
Jul	8,411	8,711	8,711	9,524	11,963	12,777	11,902	17,000
Aug	8,411	8,711	8,711	10,337	12,777	13,590	14,901	17,000
Sep	5,066	6,783	6,783	7,288	9,144	9,985	13,480	17,000

1. The analysis showed that a consistent monthly release pattern was not evident for 7.0 maf annual release years, primarily due to the variability in forecasted inflows. The monthly pattern shown was taken from a representative trace (Trace 89 for WY 2017 from the Water Supply Alternative)

Table 4.3-15
Maximum Hourly Glen Canyon Dam Releases (cfs)
Corresponding to Various Annual Release Volumes

	7.0 maf[1]	7.48 maf	7.8 maf	8.23 maf	9.0 maf	9.5 maf	9.5 to 11.0 maf	11.0 to 16.0 maf
Oct	12,458	10,006	12,458	12,458	12,458	12,458	13,475	14,218
Nov	12,783	10,603	12,783	12,783	12,783	12,783	13,748	14,506
Dec	16,711	12,458	12,458	16,711	16,711	16,711	18,009	18,794
Jan	13,459	16,711	16,711	16,711	16,711	17,524	18,986	20,354
Feb	11,924	13,504	13,504	13,504	14,404	14,404	18,422	21,047
Mar	10,000	12,458	12,458	12,458	13,271	13,271	15,076	18,334
Apr	10,000	10,603	12,783	12,783	12,783	13,624	14,827	17,926
May	10,000	12,458	12,458	12,458	13,271	16,711	14,223	19,149
Jun	11,276	12,783	12,783	13,624	17,144	18,825	18,185	25,000
Jul	14,411	16,711	16,711	17,524	19,963	20,777	19,902	25,000
Aug	14,411	16,711	16,711	18,337	20,777	21,590	22,901	25,000
Sep	10,066	12,783	12,783	13,288	17,144	17,985	21,480	25,000

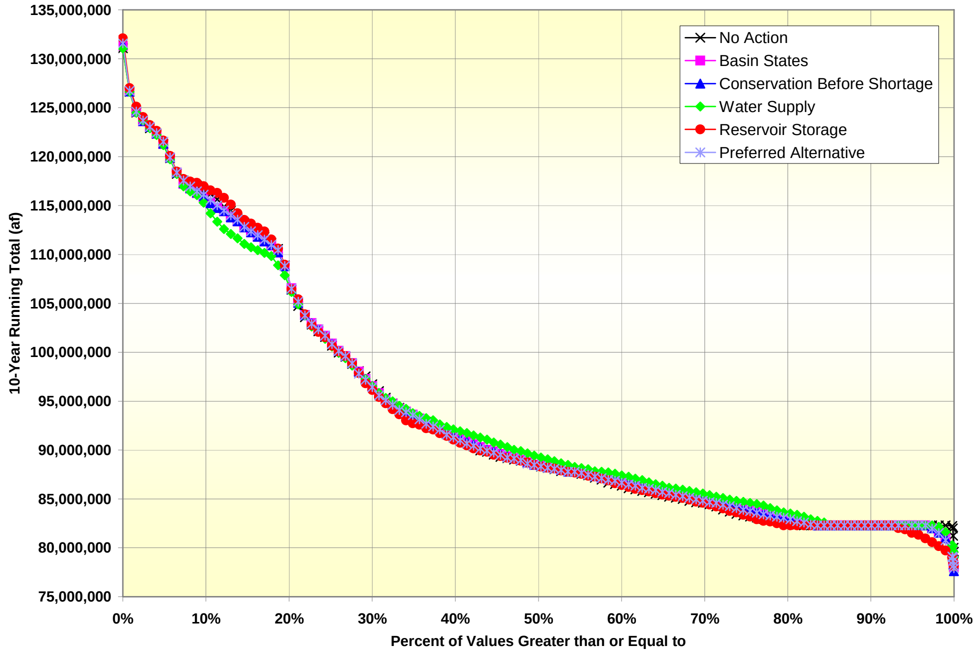
1. The analysis showed that a consistent monthly release pattern was not evident for 7.0 maf annual release years, primarily due to the variability in forecasted inflows. The monthly pattern shown was taken from a representative trace (Trace 89 for WY 2017 from the Water Supply Alternative)

4.3.3.2 10-year Running Total of Glen Canyon Dam Releases

Figure 4.3-15 compares the 10-year running totals of the Glen Canyon Dam water year releases under the action alternatives to the No Action Alternative. The values used to compute the 10-year running total for 2008 through 2017 included a combination of historical values for years prior to 2006, projections from the 24-month study for 2007 (Section 4.2 and Appendix A), and output from the CRSS model for 2008 and later. The upper limit of the 10-year running total was similar under the No Action Alternative and the action alternatives and equaled approximately 131 maf. The 10-year running total under all of the alternatives, including the No Action Alternative, was always above 75 maf.

The 10-year running total under the No Action Alternative was less than 82.3 maf in less than one percent of the years with a minimum value of 79.6 maf. The 10-year running totals under the Basin States and Conservation Before Shortage alternatives, and the Preferred Alternative were less than 82.3 maf in approximately three percent of the years and the minimum value was 77.6 maf. The 10-year running total under the Water Supply Alternative was less than 82.3 maf in two percent of the years and the minimum value was 79.0 maf. The 10-year running total under the Reservoir Storage Alternative was less than 82.3 maf in approximately 7.2 percent of the years and the minimum value was 78.1 maf.

Figure 4.3-15
Glen Canyon Dam 10-Year Running Total of Annual Releases
Comparison of Action Alternatives to No Action Alternative
Water Years 2008 through 2060



4.3.3.3 Beach/Habitat-Building Flows

The frequencies at which BHBF releases from Glen Canyon Dam would occur under the No Action Alternative and under the action alternatives were estimated using CRSS. The model simulates BHBF releases by using the BHBF triggering criteria (described in Appendix P, Section P-HR.1) and computes the probability of occurrence of BHBF releases for each calendar year throughout the modeling period. The results of this analysis for each alternative are presented in Appendix P (Section P-HR.1), and a summary is presented below.

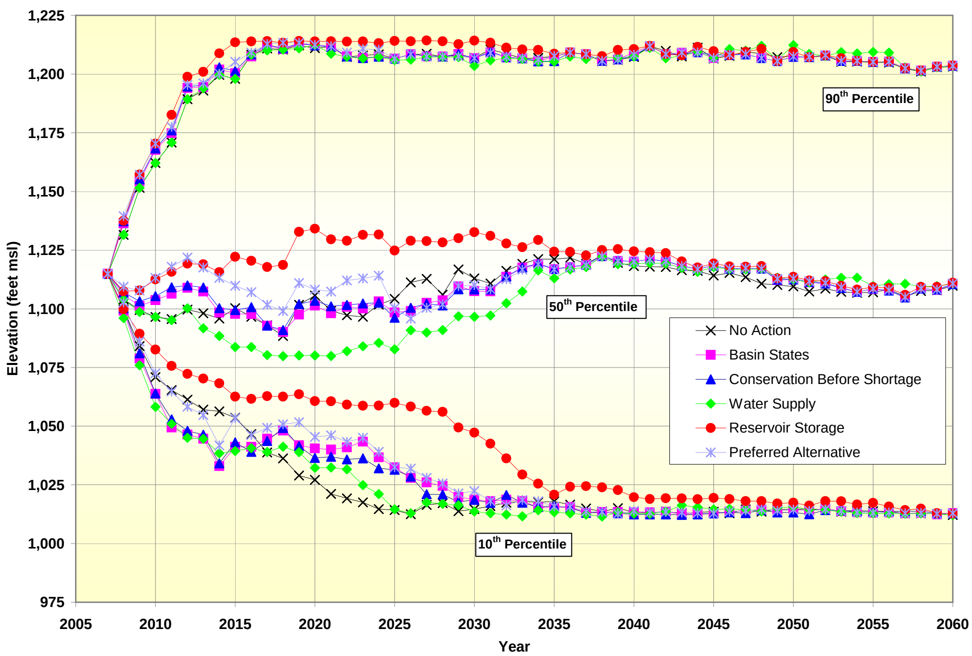
In general, the average probability that BHBF releases could be made under the No Action Alternative and the action alternatives are similar (approximately seven percent) during the interim period (2008 through 2026). The exception to this is the Reservoir Storage Alternative which has an average probability of BHBF releases that is approximately one percent higher than that of the No Action Alternative and the other action alternatives. The average probabilities for all of the alternatives are lower during the interim period as compared to the average probabilities observed during the post-interim period (2027 through 2060). This is primarily due to the low reservoir starting conditions. The average probability that BHBF releases under the No Action Alternative and the action alternatives are approximately 11.5 percent during the post-interim period (2027 through 2060). The exception to this is the Reservoir Storage Alternative which has an average probability of BHBF releases that is approximately half a percent higher than that of the No Action Alternative and the other action alternatives. The Reservoir Storage Alternative generally provides a slightly higher probability of BHBF releases than the No Action Alternative and the other action alternatives because this alternative generally provides higher reservoir elevations.

4.3.4 Lake Mead and Hoover Dam

Future elevations of Lake Mead are expected to be within the range of historic water levels (Section 3.3). However, each alternative may alter the probability (when compared to the No Action Alternative) that the reservoir may be at a given elevation in the future.

Figure 4.3-16 presents a comparison of the 90th, 50th, and 10th percentile values observed for the action alternatives to those under the No Action Alternative for Lake Mead end-of-December elevations. Under the No Action Alternative, Lake Mead is projected to fluctuate between full pool (elevation 1,219.6 feet msl) and lower elevations during the period of analysis (2008 through 2060). The 90th percentile plot increases from starting conditions to nearly full pool, about elevation 1,212 feet msl. The median elevation values (50th percentile) under the No Action Alternative fluctuated between approximately 1,090 feet msl and approximately 1,120 feet msl from 2008 through 2035. The 10th percentile values show a declining trend between 2008 and 2025, from about elevation 1,115 feet msl to about 1,015 feet msl.

Figure 4.3-16
Lake Mead End-of-December Elevations
Comparison of Action Alternatives to No Action Alternative
90th, 50th, and 10th Percentile Values



All action alternatives showed similar 90th percentile values compared to the No Action Alternative. Lake Mead elevations depicted in Figure 4.3-16 represent values at the end of December which is when lake elevations are typically at a seasonal high. Conversely, the Lake Mead elevation generally reaches its seasonal low in July.

Values at the 50th percentile under the Basin States and Conservation Before Shortage alternatives, and the Preferred Alternative were at or above the No Action Alternative prior to 2025. The Water Supply Alternative had lower 50th percentile values than the No Action Alternative during the interim period. The Reservoir Storage Alternative had higher 50th percentile values than the No Action Alternative throughout the entire period. During the interim period, the 10th percentile values for the Basin States, Conservation Before Shortage, and Water Supply alternatives, and the Preferred Alternative were higher than the No Action Alternative, and the values for the Reservoir Storage Alternative were significantly higher than the No Action Alternative.

Table 4.3-16 provides a summary of the data illustrated in Figure 4.3-16 which reflects the 90th, 50th, and 10th percentile end-of-December elevations for Lake Mead observed under the No Action Alternative and the action alternatives. The values presented in this table include those for years 2026 and 2060 only.

Table 4.3-16
Lake Mead End-of-December Elevations (feet msl)
Comparison of Action Alternatives to No Action Alternative
90th , 50th , and 10th Percentile Values

Alternative	Year 2026			Year 2060		
	90th Percentile	50th Percentile	10th Percentile	90th Percentile	50th Percentile	10th Percentile
No Action	1,208.27	1,111.31	1,012.48	1,203.15	1,109.73	1,012.14
Basin States	1,208.44	1,099.06	1,027.98	1,203.52	1,110.50	1,012.95
Conservation Before Shortage	1,208.44	1,100.41	1,028.45	1,203.52	1,110.50	1,012.87
Water Supply	1,206.11	1,090.89	1,012.88	1,203.43	1,110.66	1,012.14
Reservoir Storage	1,214.02	1,129.00	1,058.40	1,203.62	1,111.10	1,012.74
Preferred Alternative	1,208.44	1,095.83	1,031.95	1,203.52	1,110.75	1,012.93

The 90th percentile values in year 2026 vary little between the action alternatives and the No Action Alternative. The exception to this is the Reservoir Storage Alternative which is approximately seven feet higher than that of the No Action Alternative.

The 50th percentile values for the Basin States, Conservation Before Shortage, and Water Supply alternatives, and the Preferred Alternative in year 2026 are approximately 12, 11, 20, and 16 feet lower than that of the No Action Alternative, respectively. In contrast, the 50th percentile value for the Reservoir Storage Alternative in year 2026 is approximately 18 feet higher than that of the No Action Alternative.

The 10th percentile values for the Basin States, Conservation Before Shortage, Water Supply, and Reservoir Storage alternatives, and the Preferred Alternative were all higher than that of No Action Alternative in year 2026 (Table 4.3-16). The greatest difference of elevations observed occurs between the Reservoir Storage Alternative and No Action Alternative, which is about 46 feet.

Figure 4.3-17 illustrates the results for exceedence values above an elevation of 1,200 feet msl, nearly the full pool elevation of Lake Mead. All of the action alternatives were very similar to the No Action Alternative throughout the modeled years, with exceedence values ranging between zero and 20 percent.

Figure 4.3-17
Lake Mead End-of-December Elevations
Comparison of Action Alternatives to No Action Alternative
Percent of Values Greater Than or Equal to Elevation 1,200 feet msl

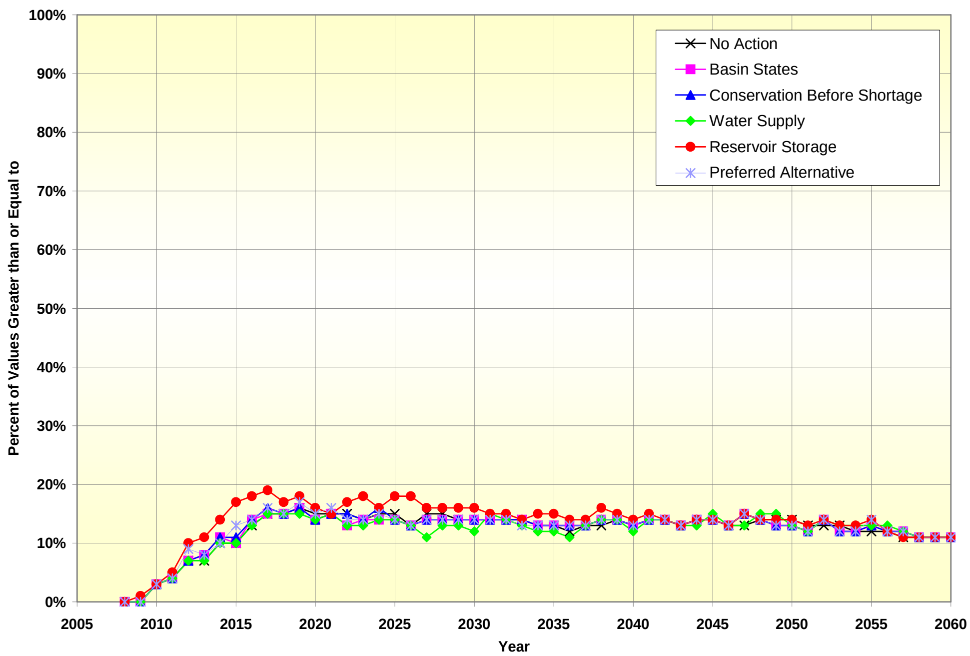


Table 4.3-17 provides a summary of the exceedence values for elevation 1,200 feet msl for selected years. As listed in this table, the exceedence values for the alternatives are similar, although the Reservoir Storage Alternative provides slightly higher exceedence values.

Table 4.3-17
Lake Mead End-of-December Elevations
Comparison of Action Alternatives to No Action Alternative
Percent of Values Greater Than or Equal to Elevation 1,200 feet msl

Alternatives	Year						
	2008	2016	2026	2030	2040	2050	2060
No Action	0	13	13	14	13	14	11
Basin States	0	14	13	14	13	13	11
Conservation Before Shortage	0	14	13	14	13	13	11
Water Supply	0	13	13	12	12	13	11
Reservoir Storage	0	18	18	16	14	14	11
Preferred Alternative	0	14	13	14	13	13	11

Figure 4.3-18 illustrates the frequency that future Lake Mead end-of-December elevations would be below 1,178 feet msl. Lake Mead elevations of 1,178 feet msl and 1,000 feet msl were used by the Clean Water Coalition as reference elevations for its Lake Mead water quality analysis (Systems Conveyance and Operations Program Final Environmental Impact Statement [SCOP FEIS] Clean Water Coalition 2006). The SCOP FEIS analyzed water quality changes corresponding to Lake Mead elevation drawdown from 1,178 feet msl to 1,000 feet msl. These potential Lake Mead water quality changes are discussed in Section 4.5. As shown in Figure 4.3-18, the results for the Basin States and Conservation Before Shortage alternatives, and the Preferred Alternative are similar to those of the No Action Alternative. Elevations under the Reservoir Storage Alternative were below 1,178 feet msl less frequently than those under the No Action Alternative. Elevations under the Water Supply Alternative were below 1,178 feet msl more frequently than those under the No Action Alternative.

Figure 4.3-18
Lake Mead End-of-December Elevations
Comparison of Action Alternatives to No Action Alternative
Percent of Values Less Than or Equal to Elevation 1,178 feet msl

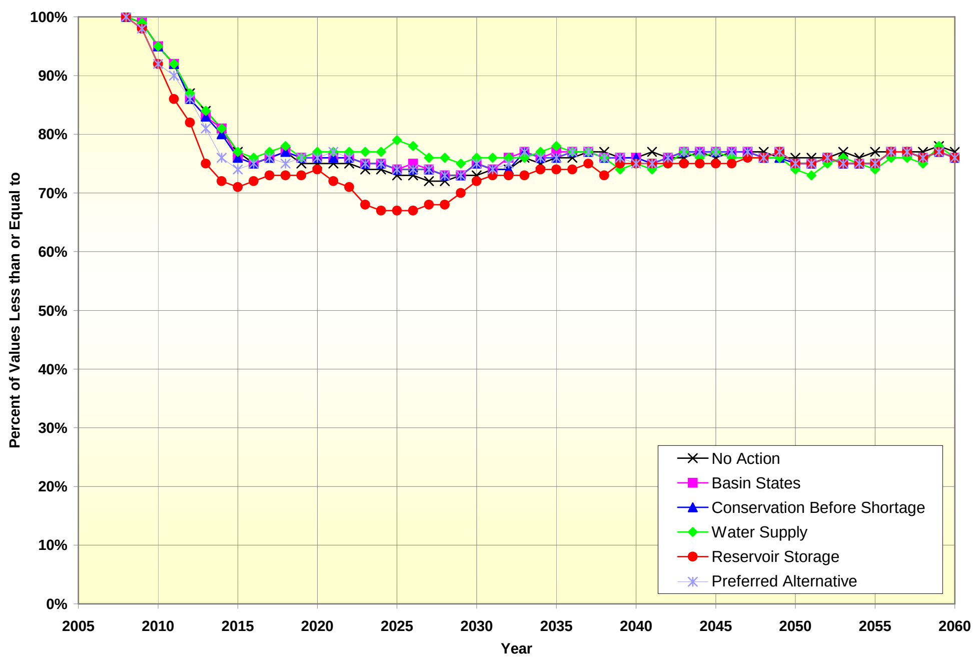


Table 4.3-18 provides a summary of the results illustrated in Figure 4.3-18 for elevation 1,178 feet msl in tabular form for selected years. As shown in Table 4.3-18, Lake Mead elevations under the Basin States and Conservation Before Shortage alternatives, and the Preferred Alternative are similar to those under the No Action Alternative. Elevations under the Reservoir Storage Alternative were below 1,178 feet msl less frequently than those under the No Action Alternative. Elevations under the Water Supply Alternative were below elevation 1,178 feet msl more frequently than those under the No Action Alternative.

Table 4.3-18
Lake Mead End-of-December Elevations
Comparison of Action Alternatives to No Action Alternative
Percent of Values Less than or Equal to Elevation 1,178 feet msl

Alternatives	Year						
	2008	2016	2026	2030	2040	2050	2060
No Action	100	75	73	73	76	76	77
Basin States	100	75	75	75	76	75	76
Conservation Before Shortage	100	75	74	75	76	75	76
Water Supply	100	76	78	76	75	74	76
Reservoir Storage	100	72	67	72	75	75	76
Preferred Alternative	100	75	74	75	75	75	76

Figure 4.3-19 illustrates the frequency that future Lake Mead end-of-July elevations would be below elevation 1,175 feet msl. Lake Mead generally reaches its seasonal low elevation in July. Below this elevation, the Pearce Bay Launch Ramp is closed and whitewater boaters must paddle an additional 16 miles to South Cove. As illustrated in Figure 4.3-19, the results for the Basin States, Conservation Before Shortage, and Water Supply alternatives, and the Preferred Alternative are similar to those of the No Action Alternative. Elevations under the Reservoir Storage Alternative were below 1,175 feet msl less frequently than those under the No Action Alternative.

Figure 4.3-19
Lake Mead End-of-July Elevations
Comparison of Action Alternatives to No Action Alternative
Percent of Values Less Than or Equal to Elevation 1,175 feet msl

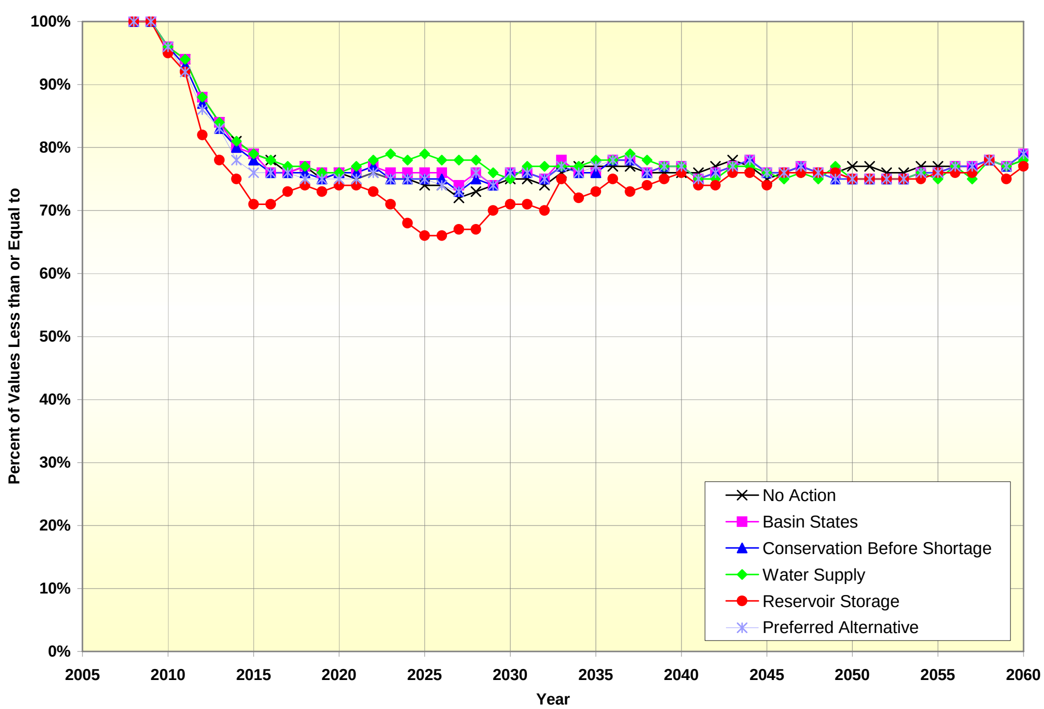


Table 4.3-19 provides a summary of the results illustrated in Figure 4.3-19 for elevation 1,175 feet msl for selected years. As shown in Table 4.3-19, Lake Mead elevations under the Basin States, Conservation Before Shortage, and Water Supply alternatives, and the Preferred Alternative are similar to those under the No Action Alternative. Elevations under the Reservoir Storage Alternative were below 1,175 feet msl less frequently than those under the No Action Alternative.

Table 4.3-19
Lake Mead End-of-July Elevations
Comparison of Action Alternatives to No Action Alternative
Percent of Values Less Than or Equal to Elevation 1,175 feet msl

Alternatives	Year						
	2008	2016	2026	2030	2040	2050	2060
No Action	100	78	74	75	76	77	78
Basin States	100	76	76	76	77	75	79
Conservation Before Shortage	100	76	75	76	77	75	79
Water Supply	100	78	78	75	77	75	78
Reservoir Storage	100	71	66	71	76	75	77
Preferred Alternative	100	76	74	76	77	75	79

Figure 4.3-20 illustrates the frequency that Lake Mead end-of-July elevations would be below elevation 1,170 feet msl, the minimum elevation needed to maintain navigation between Grand Wash and Pearce Ferry. At elevations below 1,170 feet msl, potential sediment aggradation could potentially impair navigation between these two locations. As illustrated in Figure 4.3-20, the results for the Basin States and Conservation Before Shortage alternatives, and the Preferred Alternative are similar to those observed under the No Action Alternative. Lake Mead elevations under the Water Supply Alternative were below 1,170 feet msl more frequently than those under the No Action Alternative through 2033. Elevations under the Reservoir Storage Alternative were below 1,170 feet msl less frequently than those under the No Action Alternative.

Figure 4.3-20
Lake Mead End-of-July Elevations
Comparison of Action Alternatives to No Action Alternative
Percent of Values Less Than or Equal to Elevation 1,170 feet msl

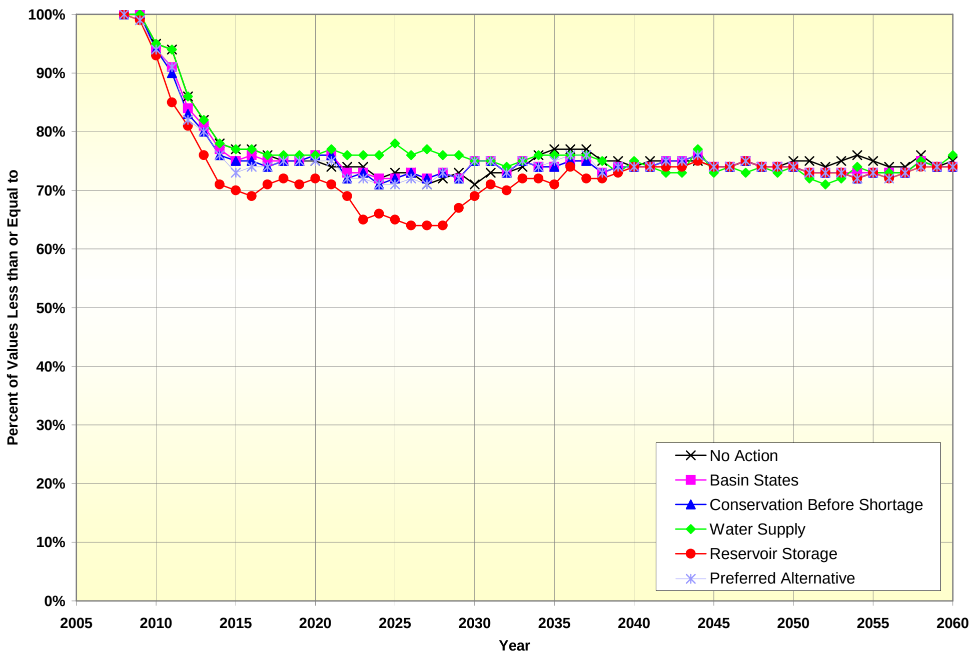


Table 4.3-20 provides a summary of the results illustrated in Figure 4.3-20 for the Lake Mead end-of-July elevation of 1,170 feet msl for selected years.

Table 4.3-20
Lake Mead End-of- July Elevations
Comparison of Action Alternatives to No Action Alternative
Percent of Values Less Than or Equal to Elevation 1,170 feet msl

Alternatives	Year						
	2008	2016	2026	2030	2040	2050	2060
No Action	100	77	73	71	74	75	75
Basin States	100	76	73	75	74	74	74
Conservation Before Shortage	100	75	73	75	74	74	74
Water Supply	100	77	76	75	75	74	76
Reservoir Storage	100	69	64	69	74	74	74
Preferred Alternative	100	74	72	75	74	74	74

Figure 4.3-21 illustrates the frequency that Lake Mead end-of-July elevations were below elevation 1,125 feet msl. At lake elevations lower than 1,125 feet msl, the Overton Beach Marina and South Cove Ramp are closed. As illustrated in Figure 4.3-21, Lake Mead elevations under the Basin States and Conservation Before Shortage alternatives, and the Preferred Alternative were below 1,125 ft msl less frequently than under the No Action Alternative prior to 2025. Elevations under the Water Supply Alternative were below 1,125 feet msl more frequently than those under the No Action Alternative between 2015 and 2041. Elevations under the Reservoir Storage Alternative were below 1,125 feet msl less frequently than those under the No Action Alternative.

Figure 4.3-21
Lake Mead End-of-July Elevations
Comparison of Action Alternatives to No Action Alternative
Percent of Values Less Than or Equal to Elevation 1,125 feet msl

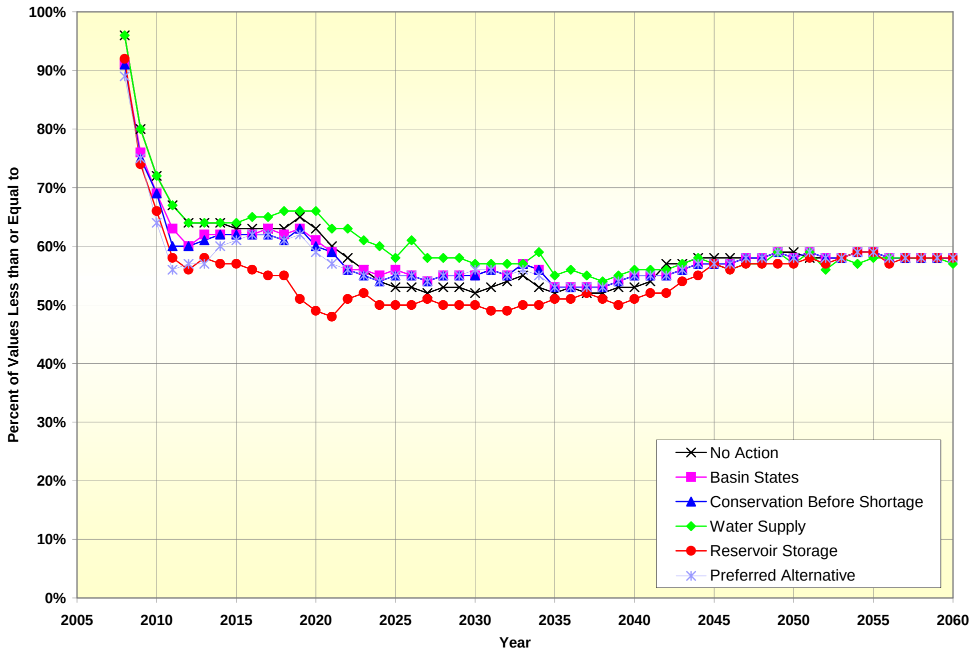


Table 4.3-21 provides a summary of the results for the Lake Mead end-of-July elevation of 1,125 feet msl for selected years.

Table 4.3-21
Lake Mead End-of-July Elevations
Comparison of Action Alternatives to No Action Alternative
Percent of Values Less Than or Equal to Elevation 1,125 feet msl

Alternatives	Year						
	2008	2016	2026	2030	2040	2050	2060
No Action	96	63	53	52	53	59	58
Basin States	91	62	55	55	55	58	58
Conservation Before Shortage	91	62	55	55	55	58	58
Water Supply	96	65	61	57	56	57	57
Reservoir Storage	92	56	50	50	51	57	58
Preferred Alternative	89	62	55	56	55	58	58

Figure 4.3-22 illustrates the frequency that Lake Mead end-of-July elevations would be below elevation 1,080 feet msl. At Lake Mead elevations below 1,080 feet msl, operations of the Lake Mead Marina Public Launch Ramp, Hemenway Public Launch Ramp, and Temple Bar Public Launch Ramp could potentially be affected. As illustrated in Figure 4.3-22, Lake Mead elevation was below 1,080 feet msl under the Reservoir Storage Alternative less frequently than under the No Action Alternative between 2010 and 2045. Elevations under the Preferred Alternative were below 1,080 feet msl less frequently than under the No Action Alternative during the period between 2010 and 2025. Elevations under the Basin States and Conservation Before Shortage alternatives were below 1,080 feet msl slightly more frequently between 2015 and 2030. Elevations under the Water Supply Alternative were below 1,080 feet msl more frequently than those under the No Action Alternative between 2015 and 2033.

Figure 4.3-22
Lake Mead End-of-July Elevations
Comparison of Action Alternatives to No Action Alternative
Percent of Values Less Than or Equal to Elevation 1,080 feet msl

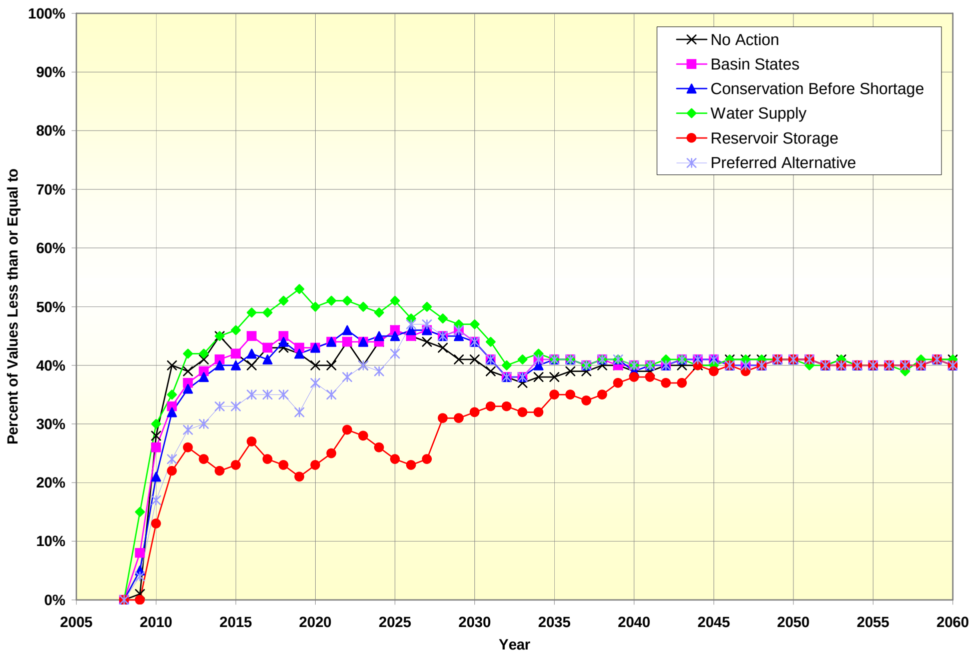


Table 4.3-22 provides a summary of the results for the Lake Mead-end-of-July elevation of 1,080 feet msl for selected years. As listed in Table 4.3-22, the action alternatives vary from the No Action Alternative mostly between years 2010 and 2030 and are similar in subsequent years.

Table 4.3-22
Lake Mead End-of-July Elevations
Comparison of Action Alternatives to No Action Alternative
Percent of Values Less Than or Equal to Elevation 1,080 feet msl

Alternatives	Year						
	2008	2016	2026	2030	2040	2050	2060
No Action	0	40	45	41	39	41	41
Basin States	0	45	45	44	40	41	40
Conservation Before Shortage	0	42	46	44	39	41	40
Water Supply	0	49	48	47	40	41	41
Reservoir Storage	0	27	23	32	38	41	40
Preferred Alternative	0	35	47	44	40	41	40

Figure 4.3-23 illustrates the frequency that Lake Mead end-of-July elevations would be below elevation 1,050 feet msl. Lake Mead elevation of 1,050 feet msl is the minimum elevation needed for efficient power generation at the Hoover Powerplant, the minimum elevation for operation of the upper intake of SNWA, and the minimum elevation for the Echo Bay Boat Launch. As illustrated in Figure 4.3-23, Lake Mead elevations under the Basin States and Conservation Before Shortage alternatives were below 1,050 feet msl less frequently than those under the No Action Alternative from 2016 through 2028. The same pattern held for the Preferred Alternative beginning in 2013. Elevations under the Water Supply Alternative were below 1,050 feet msl less frequently than under the No Action Alternative between 2018 and 2026. Elevations under the Reservoir Storage Alternative were below 1,050 feet msl less frequently than those under the No Action Alternative (lower by as much as 10 to 20 percent), reflecting higher reservoir elevations.

Figure 4.3-23
Lake Mead End-of-July Elevations
Comparison of Action Alternatives to No Action Alternative
Percent of Values Less Than or Equal to Elevation 1,050 feet msl

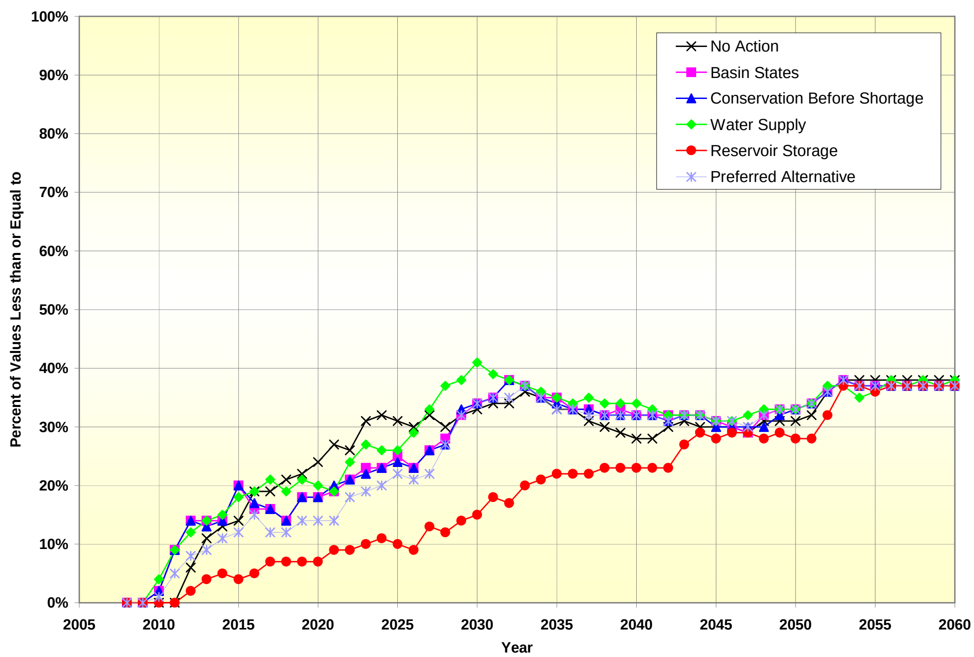


Table 4.3-23 provides a summary of the results illustrated in Figure 4.3-23 for the Lake Mead end-of-July elevation of 1,050 feet msl for selected years.

Table 4.3-23
Lake Mead End-of-July Elevations
Comparison of Action Alternatives to No Action Alternative
Percent of Values Less Than or Equal to Elevation 1,050 feet msl

Alternatives	Year						
	2008	2016	2026	2030	2040	2050	2060
No Action	0	19	30	33	28	31	38
Basin States	0	16	23	34	32	33	37
Conservation Before Shortage	0	17	23	34	32	33	37
Water Supply	0	19	29	41	34	33	38
Reservoir Storage	0	5	9	15	23	28	37
Preferred Alternative	0	15	21	34	32	33	37

Figure 4.3-24 illustrates the frequency that Lake Mead end-of-July elevations would be below elevation 1,000 feet msl. Lake Mead elevation of 1,000 feet msl is the minimum elevation needed by SNWA, to pump water from Lake Mead through its lower intake. Lake Mead elevation 1,000 feet msl was also a reference elevation for the Lake Mead water quality analysis. The SCOP FEIS analyzed water quality changes corresponding to Lake Mead elevation drawdown from 1,178 feet msl to 1,000 feet msl. These potential water quality changes are discussed in Section 4.5. As illustrated in Figure 4.3-24, Lake Mead end-of-July elevations under the No Action Alternative, and the Conservation Before Shortage and Reservoir Storage alternatives were not below 1,000 feet msl. Elevations under the Basin States Alternative and the Preferred Alternative do show some instances below 1,000 feet msl, although the frequency is very low. The maximum observed probability for elevations below 1,000 feet msl under the Water Supply Alternative is 12 percent and occurs towards the end of the interim period. Under the Basin States Alternative and the Preferred Alternative, the maximum observed probability for elevations below 1,000 feet msl is two percent and also occurs toward the end of the interim period.

Figure 4.3-24
Lake Mead End-of-July Elevations
Comparison of Action Alternatives to No Action Alternative
Percent of Values Less Than or Equal to Elevation 1,000 feet msl

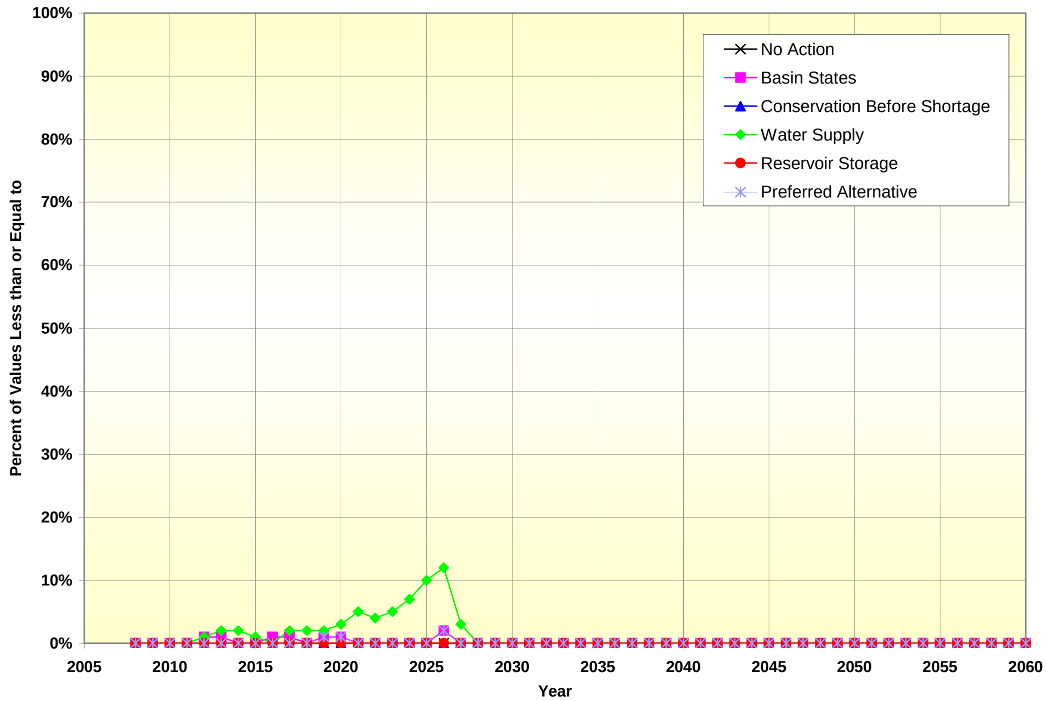


Table 4.3-24 provides a summary of the results illustrated in Figure 4.3-24 for the Lake Mead end-of-July elevation of 1,000 feet msl for selected years. The Water Supply and Basin States alternatives, and the Preferred Alternative are the only alternatives that show instances where lake elevations were below 1,000 feet msl.

Table 4.3-24
Lake Mead End-of-July Elevations
Comparison of Action Alternatives to No Action Alternative
Percent of Values Less Than or Equal to Elevation 1,000 feet msl

Alternatives	Year						
	2008	2016	2026	2030	2040	2050	2060
No Action	0	0	0	0	0	0	0
Basin States	0	1	2	0	0	0	0
Conservation Before Shortage	0	0	0	0	0	0	0
Water Supply	0	0	12	0	0	0	0
Reservoir Storage	0	0	0	0	0	0	0
Preferred Alternative	0	0	2	0	0	0	0

Figure 4.3-25 illustrates the minimum Lake Mead end-of-July elevations that were observed in the modeling of the action alternatives and No Action Alternative during the period of analysis (2008 through 2060). The minimum lake elevations under the No Action Alternative were not below 1,000 feet msl throughout the period of analysis. Similarly, the minimum lake elevations under the Conservation Before Shortage and Reservoir Storage Alternatives were not below 1,000 feet msl throughout the period of analysis. The minimum lake elevations under the Reservoir Storage Alternative are generally higher than those observed under the No Action Alternative. The minimum lake elevations under the Water Supply Alternative are generally lower than those observed under the No Action Alternative and were below 1,000 feet msl for nearly all years of the interim period. The minimum lake elevations under the Basin States Alternative are also below 1,000 feet msl during the interim period, but at higher elevations compared to the Water Supply Alternative. Lake Mead elevations modeled under the Preferred Alternative were below 1,000 feet msl, albeit only in a few years and only a few feet below elevation 1,000 feet msl. The minimum Lake Mead end-of-July elevation values under the action alternatives and the No Action Alternative remain at about 1,000 feet msl after 2030 due to the modeling assumptions after 2026.

Figure 4.3-25
Lake Mead End-of-July Elevations
Comparison of Action Alternatives to No Action Alternative
Minimum Elevation Values (feet msl)

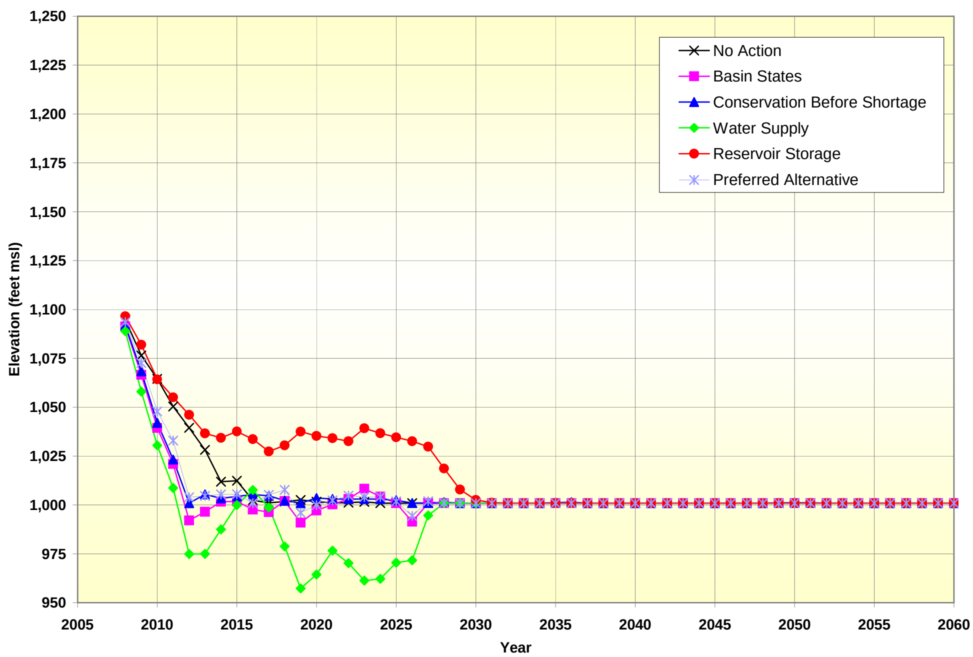


Table 4.3-25 provides a summary of the results illustrated in Figure 4.3-25 for the Lake Mead end-of-July minimum elevations for selected years. As listed in this table, the greatest variability between the action alternatives and the No Action Alternative occurs during the interim period.

Table 4.3-25
Lake Mead End-of-July Elevations
Comparison of Action Alternatives to No Action Alternative
Minimum Elevation Values (feet msl)

Alternatives	Year						
	2008	2016	2026	2030	2040	2050	2060
No Action	1,094.8	1,002.4	1,000.9	1,000.9	1,000.9	1,000.9	1,000.9
Basin States	1,091.3	997.7	991.4	1,000.9	1,000.9	1,000.9	1,000.9
Conservation Before Shortage	1,091.9	1,005.3	1,001.0	1,000.9	1,000.9	1,001.1	1,000.9
Water Supply	1,088.9	1,007.6	971.7	1,000.9	1,000.9	1,000.9	1,000.9
Reservoir Storage	1,096.5	1,033.7	1,032.6	1,002.6	1,000.9	1,000.9	1,000.9
Preferred Alternative	1,093.5	1,000.9	994.4	1,000.9	1,000.9	1,000.9	1,000.9

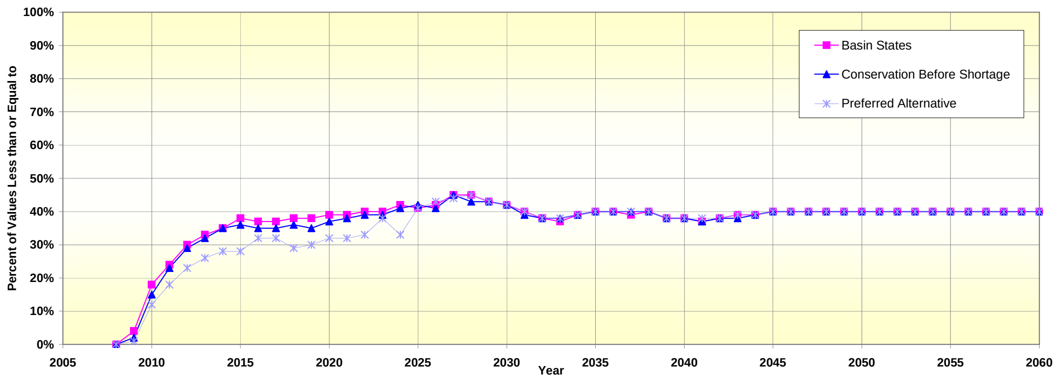
4.3.4.1 Probability of Reaching Other Key Lake Mead Elevations

The Basin States Alternative and the Preferred Alternative provide discrete levels of shortage associated with specific Lake Mead elevations (Section 2.3 and Section 2.7, respectively). These alternatives provide for shortages of 333 kaf, 417 kaf, and 500 kaf to users within the Lower Division states at Lake Mead elevations of 1,075 feet msl, 1,050 feet msl, and 1,025 feet msl, respectively. Additionally, when Lake Mead is below elevation 1,025 feet msl, additional consultations would occur under the Basin States Alternative and the Preferred Alternative to discuss further measures that may be undertaken consistent with the Law of the River. Lake Mead elevations of 1,075 feet msl, 1,050 feet msl, and 1,025 feet msl are also the conservation trigger elevations provided in the Conservation Before Shortage Alternative and correlate with voluntary water conservation actions of 400 kaf, 500 kaf, and 600 kaf, respectively.

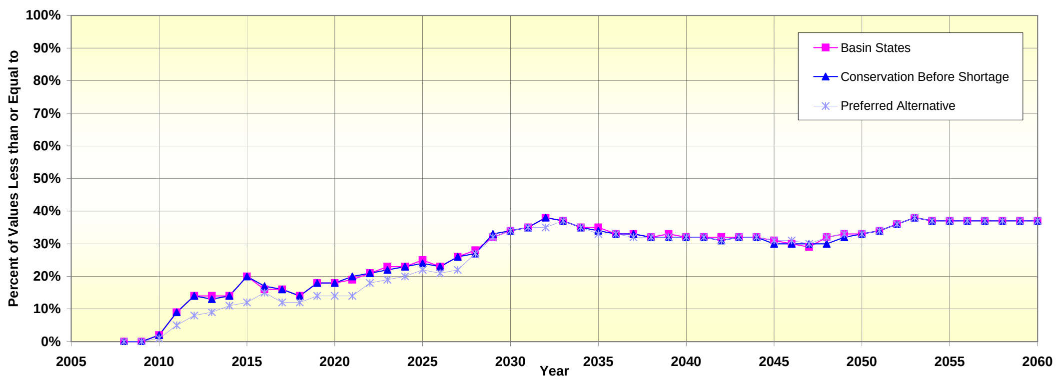
Figure 4.3-26 compares the percent of values less than or equal to the shortage trigger elevations of Lake Mead (1,075 feet msl, 1,050 feet msl, and 1,025 feet msl) under the Basin States and Conservation Before Shortage Alternatives, and the Preferred Alternative. These three key elevations are relevant only to the Basin States and Conservation Before Shortage Alternatives, and the Preferred Alternative, and therefore, the plots for the No Action Alternative, and the Water Supply and Reservoir Storage Alternatives are not shown. Figure 4.3-26 is best used to assess the probability of occurrence of the shortages or conservation actions associated with the three different trigger elevations. For example, in 2026, the probability that Lake Mead would be below the trigger elevation of 1,075 feet msl is 42 percent under the Basin States Alternative and Preferred Alternative and 41 percent under the Conservation Before Shortage Alternative. Additional comparisons of the probabilities are provided in tabular format in Table 4.3-26, Table 4.3-27, and Table 4.3-28.

Figure 4.3-26
Lake Mead End-of-July Elevations
Comparison of Action Alternatives
Percent of Values Less Than or Equal to Shortage Trigger Elevations of Lake Mead

Elevation 1,075 feet msl



Elevation 1,050 feet msl



Elevation 1,025 feet msl

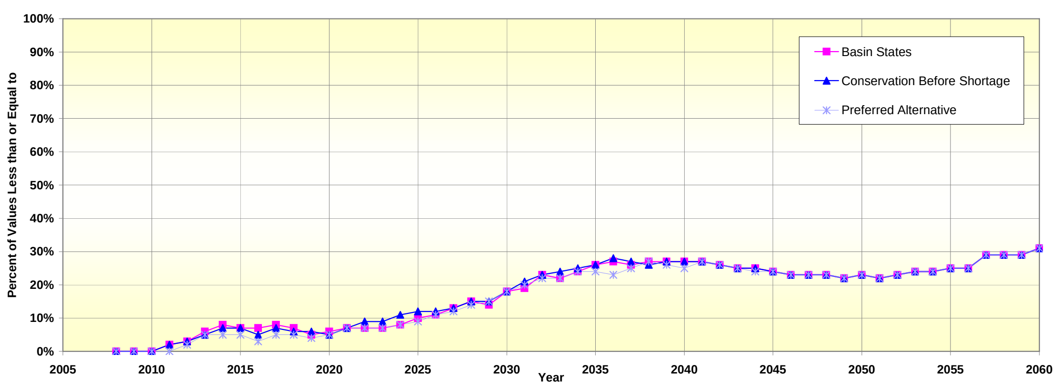


Table 4.3-26
Lake Mead End-of-July Elevations
Comparison of Action Alternatives
Percent of Values Less Than or Equal to Elevation 1,075 feet msl

Alternatives	Year						
	2008	2016	2026	2030	2040	2050	2060
Basin States	0	37	42	42	38	40	40
Conservation Before Shortage	0	35	41	42	38	40	40
Preferred Alternative	0	32	43	42	38	40	40

Table 4.3-27
Lake Mead End-of-July Elevations
Comparison of Action Alternatives
Percent of Values Less Than or Equal to Elevation 1,050 feet msl

Alternatives	Year						
	2008	2016	2026	2030	2040	2050	2060
Basin States	0	16	23	34	32	33	37
Conservation Before Shortage	0	17	23	34	32	33	37
Preferred Alternative	0	15	21	34	32	33	37

Table 4.3-28
Lake Mead End-of-July Elevations
Comparison of Action Alternatives
Percent of Values Less Than or Equal to Elevation 1,025 feet msl

Alternatives	Year						
	2008	2016	2026	2030	2040	2050	2060
Basin States	0	7	11	18	27	23	31
Conservation Before Shortage	0	5	12	18	27	23	31
Preferred Alternative	0	3	11	18	25	23	31

4.3.4.2 Storage of Conserved Water in Lake Mead

Under the Basin States, Conservation Before Shortage, and Reservoir Storage Alternatives, and the Preferred Alternative, the assumptions made for the storage and delivery mechanism for conserved system and non-system water could potentially impact the volume of water in storage in Lake Mead. An overall increase in the volume of water in Lake Mead is likely due to the system assessment whereby a percentage of the conserved water is retained in Lake Mead.

An analysis of the sensitivity of the volume of water in storage in Lake Mead to the storage and delivery mechanism was performed by comparing these four alternatives with and without the mechanism in place. Without the mechanism in place, it was assumed that the voluntary shortages (i.e., reduced water deliveries due to conservation proposed to occur at and below Lake Mead elevations of 1,075 feet msl) proposed in the Conservation Before Shortage Alternative would occur. Under this assumption, the conserved water would remain in Lake Mead. All other conservation activities assumed to be associated with the storage and delivery mechanism as described in Appendix M were assumed not to exist for the Conservation Before Shortage, Basin States, and Reservoir Storage Alternatives, and the Preferred Alternative.

Figure 4.3-27 presents a comparison of the 90th, 50th, and 10th percentile values observed for the action alternatives to those under the No Action Alternative. This figure illustrates Lake Mead elevations for the Basin States, Conservation Before Shortage, and Reservoir Storage Alternatives, and the Preferred Alternative if the storage and delivery mechanism is not in place. Lake Mead elevations illustrated in Figure 4.3-27 for these alternatives can be contrasted to those shown in Figure 4.3-16 which shows Lake Mead elevations for these alternatives if the storage and delivery mechanism is in place. As illustrated by this comparison, the inclusion of mechanism in these alternatives would have a tendency to provide higher Lake Mead elevations.

Figure 4.3-27
Lake Mead End-of-December Elevations
Comparison of Action Alternatives With Storage and Delivery Mechanism Removed to No Action Alternative
90th, 50th, and 10th Percentile Values

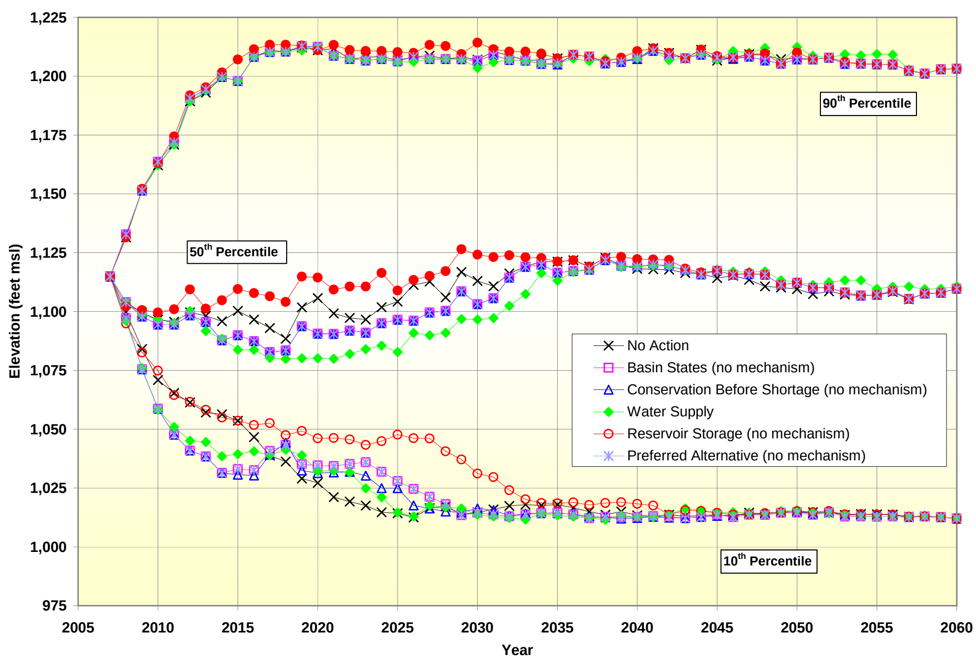


Figure 4.3-28 compares the 90th, 50th, and 10th percentile Lake Mead elevations for the Basin States, Conservation Before Shortage, and Reservoir Storage Alternatives, and the Preferred Alternative with a storage and delivery mechanism, to the same alternatives without a storage and delivery mechanism.

Figure 4.3-28
Lake Mead End-of-December Elevations
Comparison of Action Alternatives With and Without a Storage and Delivery Mechanism
90th, 50th, and 10th Percentile Values

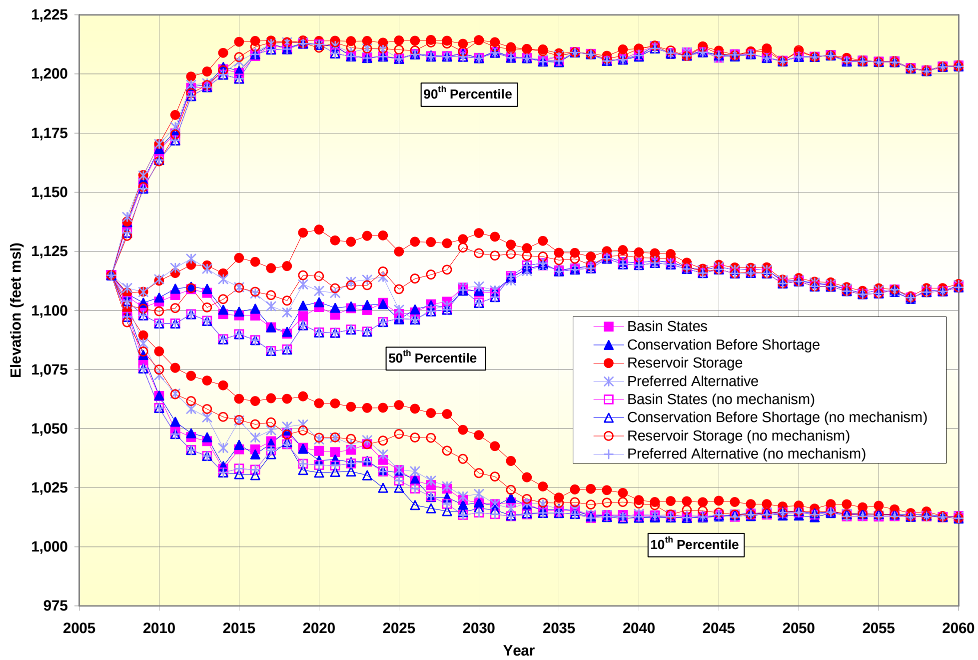


Table 4.3-29 provides a summary of the increases in Lake Mead elevations for selected years that can be attributed to the inclusion of the storage and delivery mechanism in the Basin States, Conservation Before Shortage, and Reservoir Storage Alternatives, and the Preferred Alternative. As listed in this table for the 50th and 10th percentile values, the storage and delivery mechanism could potentially provide higher Lake Mead elevations, by as much as 15.6 feet under the Reservoir Storage Alternative, 13.3 feet under the Conservation Before Shortage Alternative, 10.3 feet under the Basin States Alternative, and 19.7 feet under the Preferred Alternative.

Table 4.3-29
Lake Mead End-of-December Elevations
Increase/Decrease ( ) in Lake Mead Elevations (feet) Resulting From a Storage and Delivery Mechanism
Comparison of Action Alternatives With and Without a Storage and Delivery Mechanism
90th, 50th, and 10th Percentile Values

Year	Basin States			Conservation Before Shortage		
	90th Percentile	50th Percentile	10th Percentile	90th Percentile	50th Percentile	10th Percentile
2008	3.6	2.0	1.9	4.5	3.0	2.9
2016	(0.7)	10.3	8.6	0.2	13.3	8.7
2026	0.2	2.9	3.4	0.2	4.3	10.8
2030	0.2	4.4	4.2	0.2	5.2	2.4
2040	1.5	0.9	0.5	0.5	1.0	0.1
2050	0.3	0.2	(0.1)	0.3	0.2	(1.8)
2060	0.4	0.8	0.8	0.4	0.8	0.9
Year	Reservoir Storage			Preferred Alternative		
	90th Percentile	50th Percentile	10th Percentile	90th Percentile	50th Percentile	10th Percentile
2008	6.1	5.3	4.9	6.7	5.5	5.5
2016	2.5	12.7	9.8	0.9	19.7	13.6
2026	4.2	15.6	12.2	0.2	(0.3)	7.3
2030	0.1	8.5	16.1	0.2	7.0	7.9
2040	0.1	2.3	1.5	0.5	0.9	1.2
2050	(0.6)	1.4	2.3	0.4	0.5	(0.1)
2060	0.5	1.4	0.6	0.4	1.0	0.8

4.3.5 Hoover Dam to Davis Dam

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 one percent of the total annual flow in this reach. During the 10-year period between 1996 and 2005, the annual Hoover Dam releases have ranged between 8.274 maf and 12.774 maf, and averaged 10.415 maf.

Future annual and monthly releases may be affected by the proposed federal action (Section 3.3). Each action alternative may alter the probability (when compared to the No Action Alternative) of the magnitude and timing of particular releases. However, due to the presence of Lake Mohave immediately downstream, these potential changes in releases will have an effect only on hydropower generation.

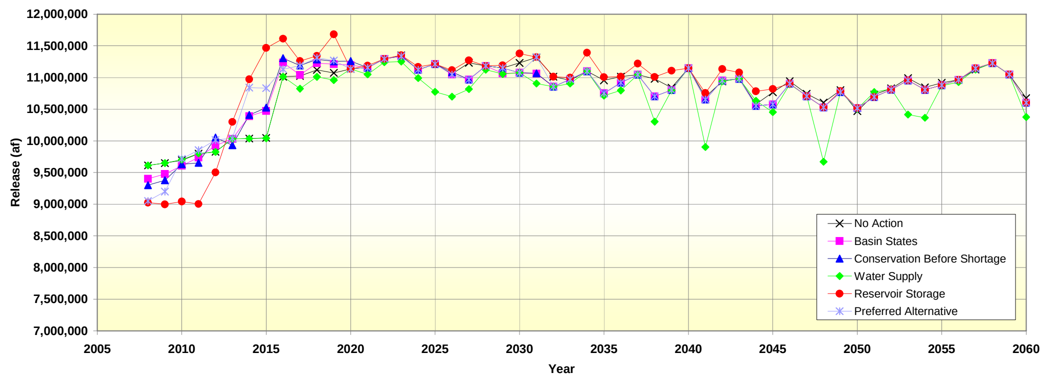
Figure 4.3-29 presents a comparison of the 90th, 50th, and 10th percentile values observed under the action alternatives and the No Action Alternative for Hoover Dam annual (calendar year) releases. The greatest variability between the action alternatives and the No Action Alternative generally occurs during the period between 2008 and 2026. Also, the greatest variability occurs between the Reservoir Storage Alternative and the No Action Alternative and is consistent with the underlying strategy of the Reservoir Storage Alternative which is to maintain more water in storage. This is facilitated through more frequent involuntary delivery reductions and is reflected in the 50th and 10th percentile values which are lower for this alternative between 2008 and 2026. Since more water is held in storage, as compared to the No Action Alternative, the Reservoir Storage Alternative provides more opportunities for more frequent and higher flood control and surplus releases, which is reflected in the 90th percentile values for this alternative. In contrast, the strategy of the Water Supply Alternative is to meet the water users' delivery requirements with less regard to preserving water in storage. As such, the 50th and 10th percentile values under the Water Supply Alternative show that more water is delivered under this alternative between 2008 and 2026, as compared to the No Action Alternative. The ranges of water releases at the 90th, 50th, and 10th percentiles that occur under the Basin States and Conservation Before Shortage Alternatives, and the Preferred Alternative generally coincide with the range of releases observed under the No Action Alternative and differences, where they occur, are relatively small.

Another observation relates to the 50th and 10th percentile annual Hoover Dam release volumes that are slightly below those of the No Action Alternative under the Basin States, Conservation Before Shortage, and Reservoir Storage Alternatives, and the Preferred Alternative after 2026. This difference can be attributed to the assumption that SNWA would develop additional permanent non-system water supplies from sources located downstream of Hoover Dam (described as system augmentation in Appendix M) that would be delivered to Lake Mead through some form of transfer or exchange with another agency that has a point of delivery also located downstream of Hoover Dam, thereby reducing the release from Hoover Dam.

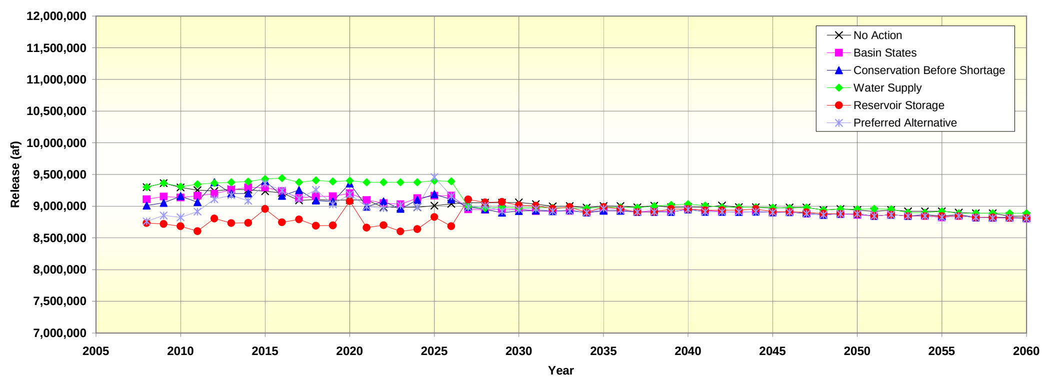
Figure 4.3-30 illustrates the cumulative distribution of Hoover Dam annual releases under the action alternatives and the No Action Alternative for the interim period (2008 through 2060). The observed minimum and maximum annual releases under the No Action Alternative are 7.46 maf and 17.13 maf, respectively. By comparison, the minimum annual release under the action alternatives is 7.3 maf, and occurs under the Conservation Before Shortage Alternative; the maximum annual release is 17.16 maf, and occurs under the Basin States, Conservation Before Shortage, and Reservoir Storage Alternatives, and the Preferred Alternative. In general, the observed annual release volumes under the Basin States and Conservation Before Shortage Alternatives, and the Preferred Alternative are similar to those observed under the No Action Alternative. The annual releases observed under the Water Supply Alternative are generally higher than those observed under the No Action Alternative. The annual releases observed under the Reservoir Storage Alternative are generally lower than those observed under the No Action Alternative.

Figure 4.3-29
Hoover Dam Annual Releases
Comparison of Action Alternatives to No Action Alternative
90th, 50th and 10th Percentile Values

90th Percentile



50th Percentile



10th Percentile

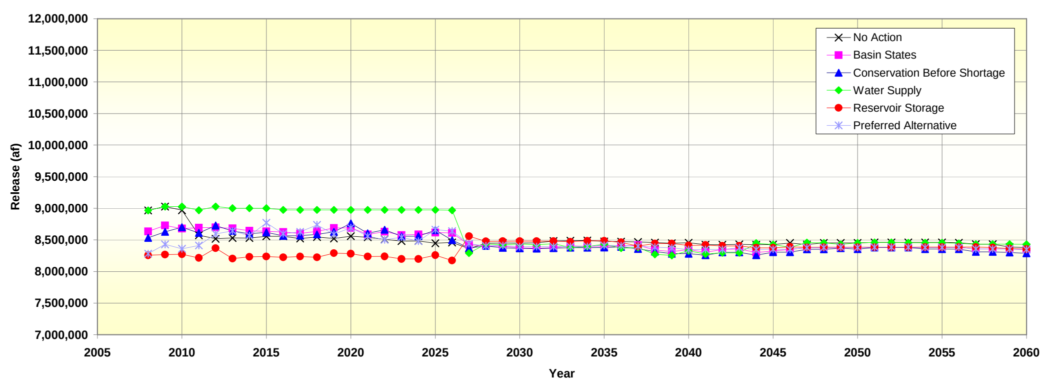


Figure 4.3-30
Hoover Dam Cumulative Annual Releases
Comparison of Action Alternatives to No Action Alternative
Years 2008 through 2026

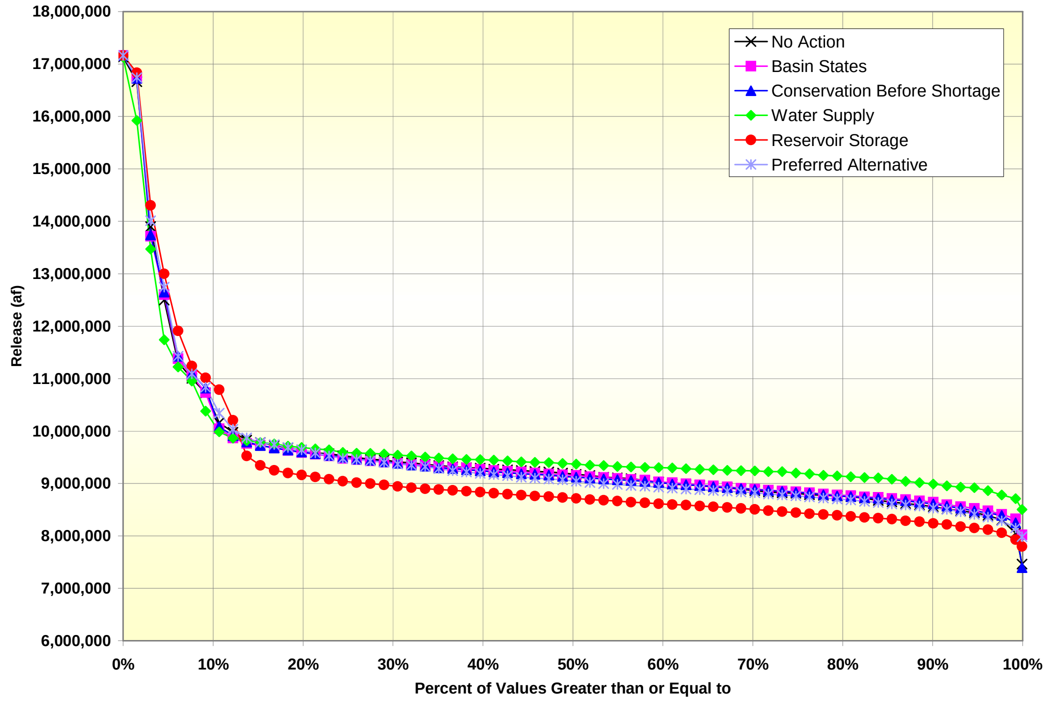


Figure 4.3-31 illustrates the cumulative distribution of Hoover Dam annual releases under the action alternatives and the No Action Alternative for years 2008 through 2060. The observed annual releases under all the alternatives (including the No Action Alternative) fluctuate between 6.33 maf and about 17.2 maf. The minimum annual release is 6.33 maf and occurs under the Water Supply Alternative, although it only occurs less than one percent of the time.

Figure 4.3-31
Hoover Dam Cumulative Annual Releases
Comparison of Action Alternatives to No Action Alternative
Years 2008 through 2060

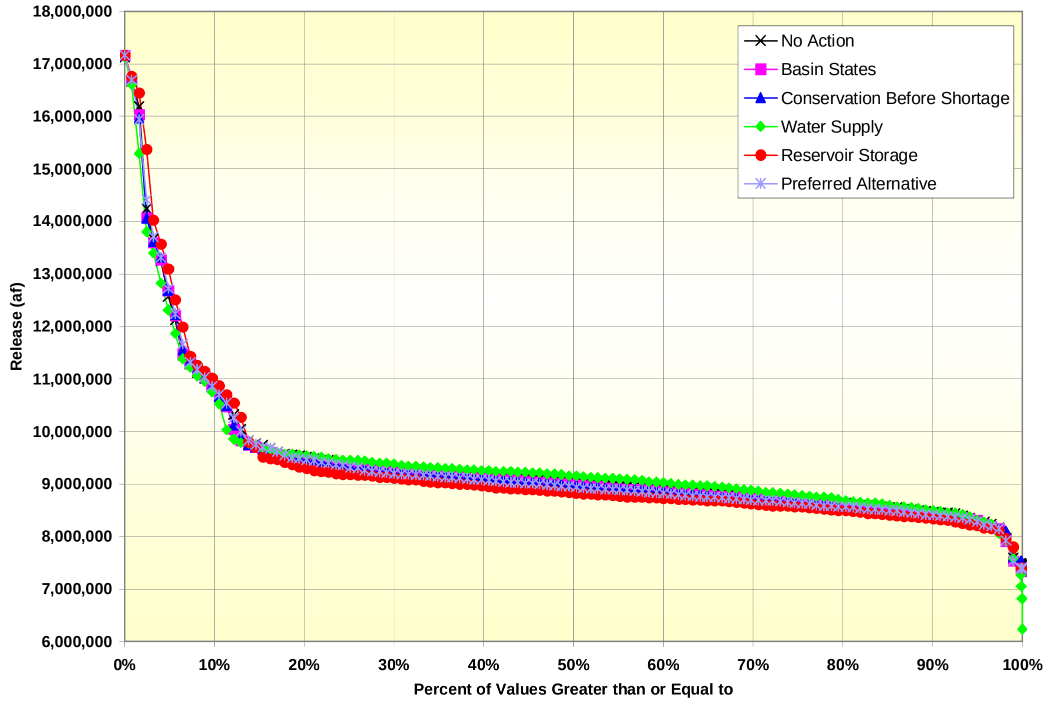


Table 4.3-30 and Table 4.3-31 provide a summary of the distribution of the Hoover Dam releases within different flow ranges of interest over the periods 2008 through 2026 and 2008 through 2060, respectively.

As shown in Table 4.3-30, the frequency of Hoover Dam releases greater than 10.0 mafy are similar under all the alternatives. The greatest variability between the action alternatives and the No Action Alternative occurs in the range of 8.01 to 10.0 mafy. The Water Supply Alternative generally provides higher annual release volumes and this is made apparent in Table 4.3-30 by the high frequency of releases in the range of 9.01 to 10.0 mafy. In contrast, the Reservoir Storage Alternative provides the lowest annual releases as illustrated by the percentage of annual releases less than 9.0 mafy.

Table 4.3-30
Hoover Dam Annual Releases
Probability of Occurrence of Different Annual Release Volumes (percent)
Comparison of Action Alternatives to No Action Alternative
Years 2008 through 2026

Hoover Dam Release Volumes	Alternative					
	No Action	Basin States	Conservation Before Shortage	Water Supply	Reservoir Storage	Preferred Alternative
Greater than 10.0 mafy	11.89	11.26	11.16	10.68	12.79	12.58
Between 9.01 to 10.0 mafy	48.53	50.47	49.42	78.68	14.26	40.53
Between 8.01 to 9.00 mafy	39.05	38.26	39.26	10.63	71.58	46.74
Less than or equal to 8.00 mafy	0.53	0.00	0.16	0.00	1.37	0.16
Total	100.0	100.0	100.0	100.0	100.0	100.0

As provided in Table 4.3-31 for the modeled period between 2008 to 2060, Hoover Dam releases in the range of 8.01 mafy to 10.0 mafy differ mostly under the Water Supply and Reservoir Storage Alternatives. The Water Supply Alternative provides more frequent annual releases greater than 9.0 mafy and the Reservoir Storage Alternative provides annual releases equal to or greater than 9.0 mafy less often as compared to the No Action Alternative and the other action alternatives. The other action alternatives are similar to the No Action Alternative.

Table 4.3-31
Hoover Dam Annual Releases
Probability of Occurrence of Different Annual Release Volumes (percent)
Comparison of Action Alternatives to No Action Alternative
Years 2008 through 2060

Hoover Dam Release Volumes	Alternative					
	No Action	Basin States	Conservation Before Shortage	Water Supply	Reservoir Storage	Preferred Alternative
Greater than 10.0 mafy	13.17	12.49	12.43	11.47	13.60	12.98
Between 9.01 to 10.0 mafy	38.00	36.94	36.53	49.85	24.47	33.45
Between 8.01 to 9.00 mafy	46.60	48.51	49.81	36.30	60.00	51.49
Less than or equal to 8.00 mafy	2.23	2.06	1.23	2.38	1.92	2.08
Total	100.0	100.0	100.0	100.0	100.0	100.0

4.3.5.1 Lake Mohave Water Levels

Lake Mohave is operated under a rule curve that provides specific target elevations at the end of each month (Section 3.3). The same rule curve would be used and applied in future operations under the action alternatives and the No Action Alternative. Therefore, Lake Mohave end-of-month elevations are not affected by the proposed federal action.

4.3.6 Davis Dam to Parker Dam

4.3.6.1 River Flows

River flows between Davis Dam and Parker Dam are comprised mainly of releases from Davis Dam (Lake Mohave) and tributary inflows from the Bill Williams River. During the 10-year period between 1996 and 2005, the annual Davis Dam releases have ranged between 8.1 maf and 12.6 maf and averaged 10.2 maf. Releases greater than 9.5 maf generally correspond to years when surplus or flood flow releases are made at Hoover Dam and are passed through Lake Mohave. Flows less than 8.5 maf are associated with voluntary or involuntary delivery reductions to water users in the Lower Basin.

Figure 4.3-32 presents a comparison of the 90th, 50th, and 10th percentile values for Davis Dam observed for the action alternatives to those under the No Action Alternative. The values and variability of the 90th, 50th, and 10th percentile values under the No Action Alternative and action alternatives are similar to those in Figure 4.3-29 (Hoover Dam releases) because the releases from Hoover Dam are passed through Lake Mohave. The differences are mostly due to losses attributed to evaporation at Lake Mohave, which would be the same in all of the alternatives due to rule curve operations.

Figure 4.3-33 illustrates the cumulative distribution of the Davis Dam releases for the No Action Alternative and the action alternatives during the interim period (2008 through 2060). The range and frequency of the releases under the different alternatives are similar to those shown for Hoover Dam in Figure 4.3-30. Again, the reason for this is that releases from Hoover Dam are essentially passed through Lake Mohave to meet downstream demands.

Figure 4.3-34 illustrates the cumulative distribution of the Davis Dam releases for the No Action Alternative and the action alternatives for the period 2008 through 2060. The range and frequency of the releases under the different alternatives are similar to those shown for Hoover Dam in Figure 4.3-31.

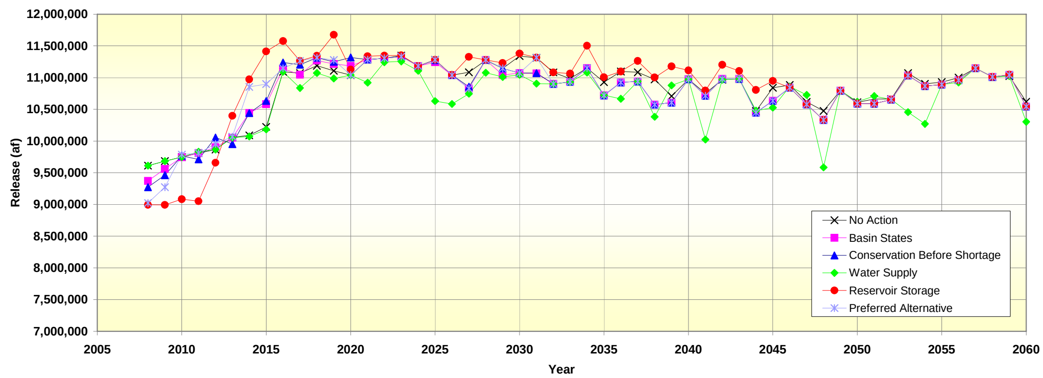
4.3.6.2 Colorado River Annual Flows Near Havasu NWR

A point located immediately downstream of the Havasu NWR was used to further analyze the river flows for this reach.

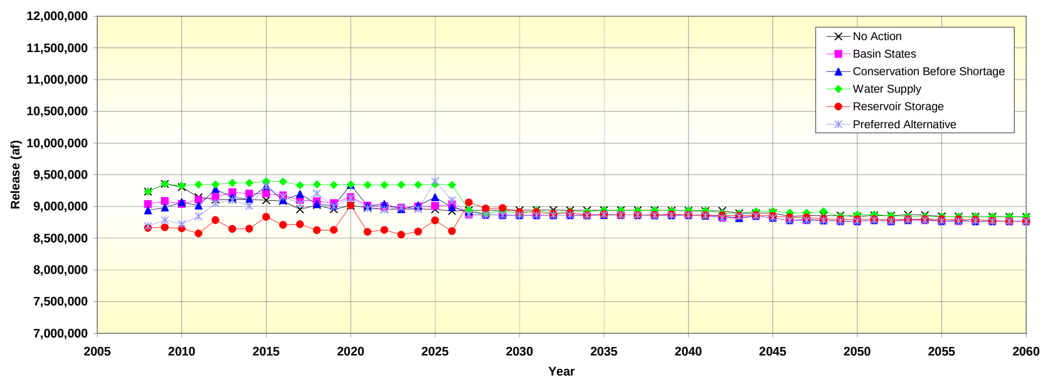
The 90th, 50th, and 10th percentile annual flow volumes at this point are shown in Figure 4.3-35. These river flows show the same general patterns that were observed in the corresponding plots for Hoover Dam and Davis Dam releases (Figure 4.3-29 and Figure 4.3-32 respectively) since those dams are operated, 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.

Figure 4.3-32
Davis Dam Annual Releases
Comparison of Action Alternatives to No Action Alternative
90th, 50th, and 10th Percentile Values

90th Percentile



50th Percentile



10th Percentile

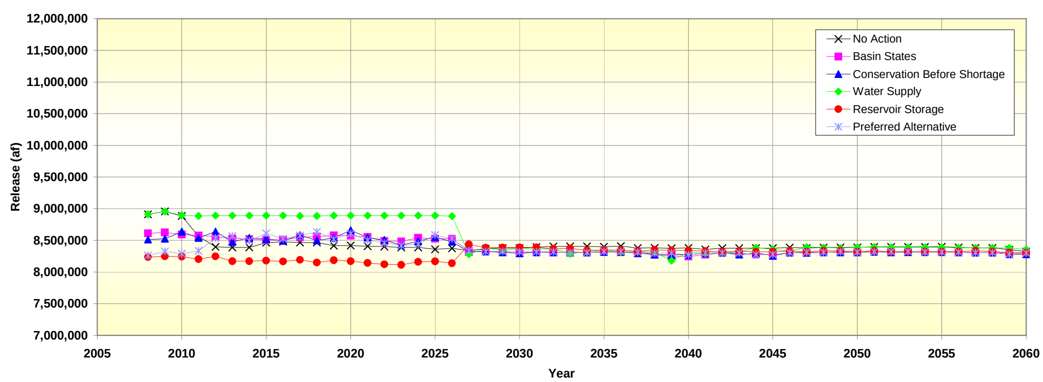


Figure 4.3-33
Davis Dam Cumulative Annual Releases
Comparison of Action Alternatives to No Action Alternative
Years 2008 through 2026

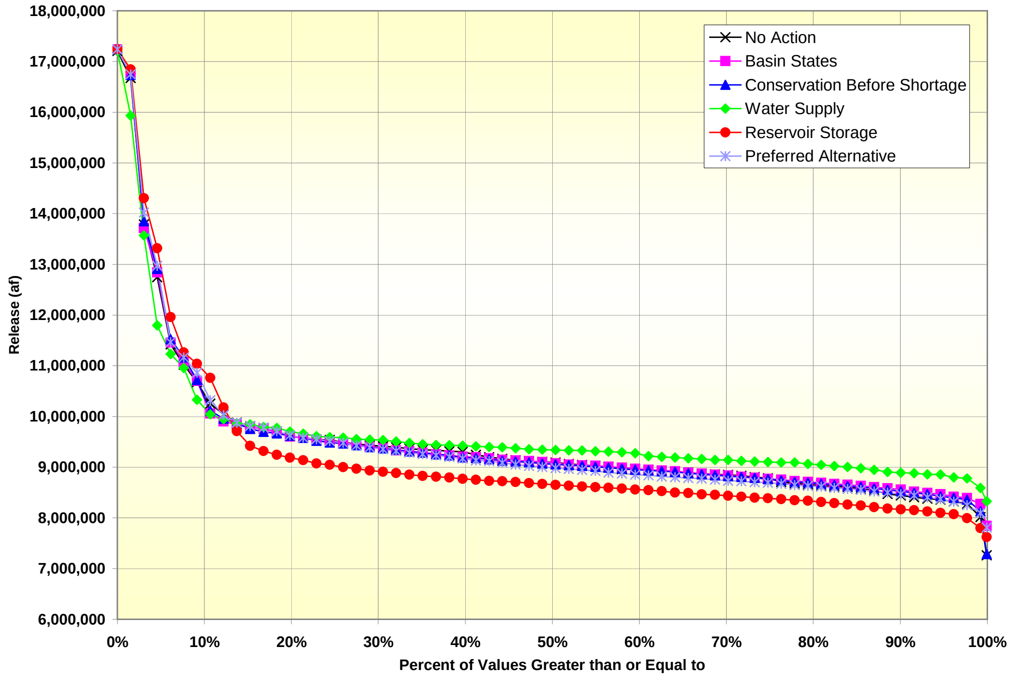


Figure 4.3-34
Davis Dam Cumulative Annual Releases
Comparison of Action Alternatives to No Action Alternative
Years 2008 through 2060

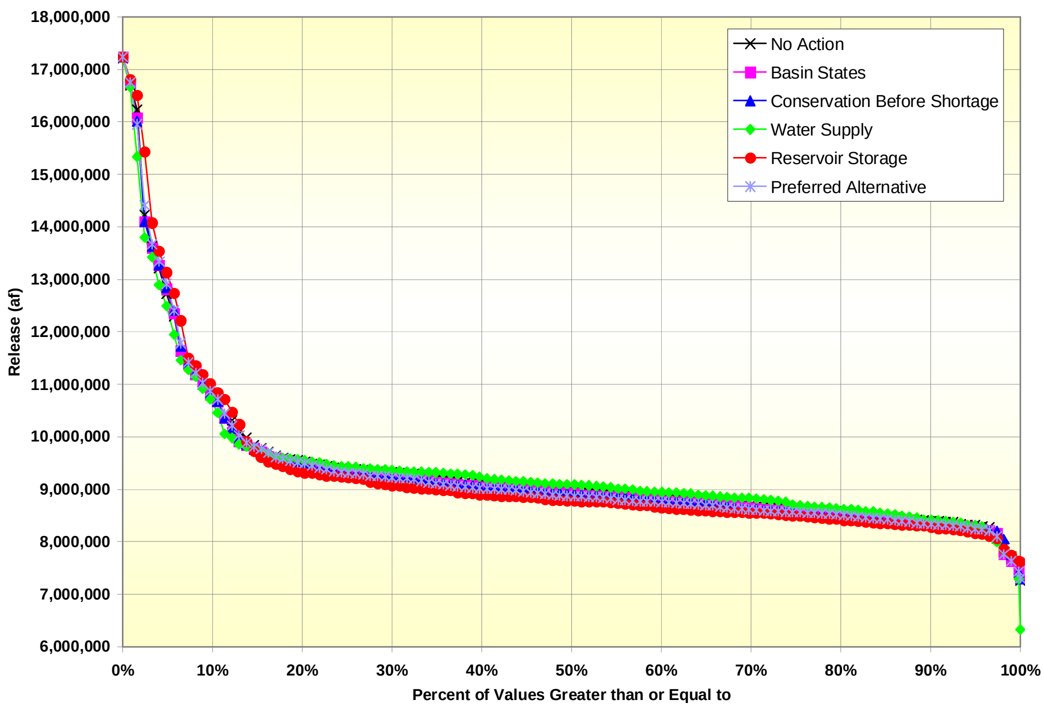


Figure 4.3-35
Colorado River Annual Flow Near Havasu NWR - RM 242.3
Comparison of Action Alternatives to No Action Alternative
90th, 50th, and 10th Percentile Values

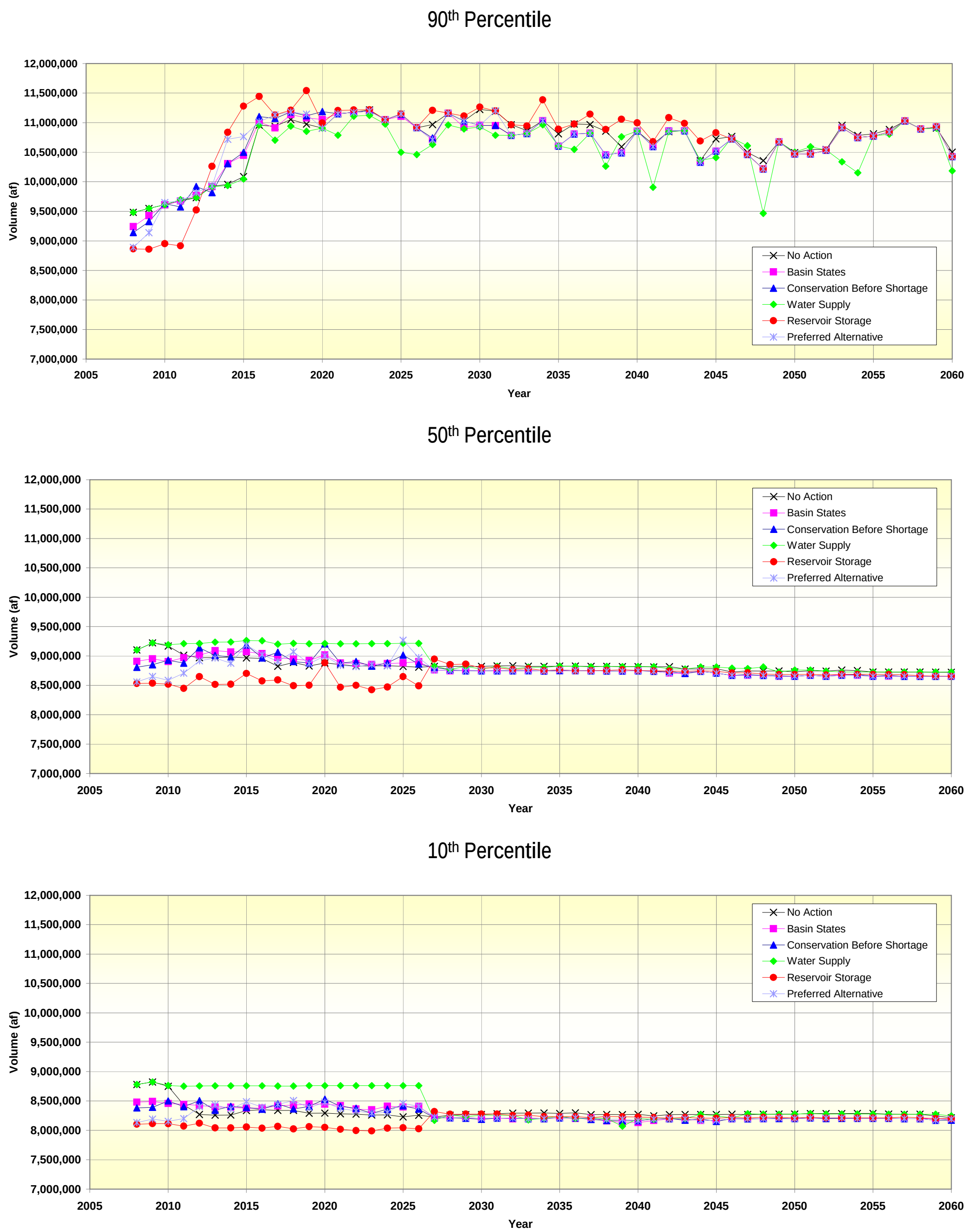


Table 4.3-32 provides a comparison of the 90th, 50th, and 10th percentile annual flow volumes between the action alternatives and the No Action Alternative for selected years.

Table 4.3-32
Colorado River Annual Flow Near Havasu NWR - RM 242.3 (maf)
Comparison of Action Alternatives to No Action Alternative
90th, 50th, and 10th Percentile Values

Alternative	Year 2016			Year 2026			Year 2040			Year 2060		
	90th	50th	10th	90th	50th	10th	90th	50th	10th	90th	50th	10th
No Action	10.959	8.957	8.350	10.913	8.809	8.256	10.858	8.818	8.271	10.501	8.721	8.214
Basin States	11.010	9.039	8.379	10.913	8.905	8.408	10.858	8.753	8.131	10.426	8.652	8.192
Conservation Before Shortage	11.104	8.967	8.360	10.916	8.862	8.363	10.858	8.746	8.162	10.426	8.654	8.172
Water Supply	10.959	9.260	8.758	10.460	9.215	8.759	10.858	8.821	8.198	10.185	8.727	8.247
Reservoir Storage	11.443	8.576	8.037	10.919	8.491	8.025	10.996	8.753	8.227	10.426	8.654	8.199
Preferred Alternative	11.015	9.023	8.395	10.913	8.971	8.407	10.858	8.746	8.166	10.426	8.652	8.192

4.3.6.3 Groundwater

Flows in the Davis Dam to Parker Dam reach are primarily composed of water released from Davis Dam (Section 3.3). Therefore, the annual median releases are representative of the annual median flows in this reach. When converted to stage, a comparison of the annual median releases for each alternative may be used as the indicator to analyze potential effects to groundwater adjacent to the river in this reach.

Figure 4.3-36 illustrates the annual median releases from Davis Dam for each alternative for the years 2008 through 2060. These are the same data shown in Figure 4.3-32 converted from acre-feet per year to cubic feet per second. In general, the median releases for the Water Supply and Reservoir Storage Alternatives bracket the median releases for the other four alternatives due primarily to the different shortage assumptions for each of the alternatives.

Table 4.3-33 compares the annual median values relative to the No Action Alternative for specific years (each action alternative value less the No Action Alternative value). Using appropriate relationships to convert flow-to-stage (LCR MSCP BA [Reclamation 2004c], Appendix J, Attachment D), these relative flow differences would result in minor reductions in river stage (on the order of 0.5 feet). Based on the relationships used in the LCR MSCP BA, Appendix K, such river stage reductions would result in corresponding reductions in groundwater elevations adjacent to the river (approximately 0.25 feet to 0.5 feet for gaining and losing reaches respectively).

Figure 4.3-36
Davis Dam Annual Releases
Comparison of Action Alternatives to No Action Alternative
Annual Median (50th Percentile) Values

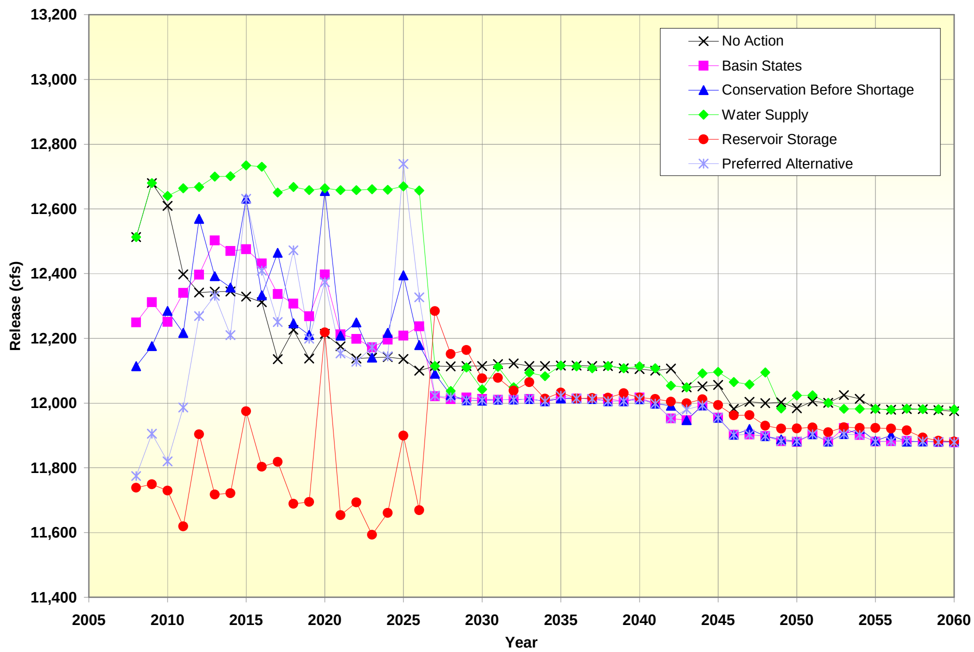


Table 4.3-33
Davis Dam Annual Median Releases
Differences of Action Alternatives Compared to No Action Alternative[1] (cfs)

Year	Basin States	Conservation Before Shortage	Water Supply	Reservoir Storage	Preferred Alternative
2008	(264)	(399)	0	(774)	(738)
2011	(57)	(181)	266	(779)	(412)
2016	119	21	418	(509)	97
2017	201	329	515	(318)	114
2026	137	79	557	(431)	227
2027	(93)	(24)	0	170	(91)
2040	(88)	(93)	8	(88)	(93)
2060	(96)	(94)	5	(94)	(96)

1 *Value of the action alternative minus the value from the No Action Alternative provides the difference shown. Values shown in parenthesis indicate that the value under the action alternative is lower than that of the No Action Alternative, i.e. a flow reduction.*

4.3.6.4 Lake Havasu Elevations

Similar to Lake Mohave, Lake Havasu is also operated under a rule curve. This method of operation provides specific target elevations at the end of each month (Section 3.3). The same rule curve would be used and applied in the future operations under the action alternatives and the No Action Alternative. Therefore, end-of-month elevations of Lake Havasu are not affected by the proposed federal action.

4.3.7 Parker Dam to Cibola Gage and Cibola Gage to Imperial Dam

Parker Dam provides the last opportunity to re-regulate Hoover Dam releases because Lake Havasu is the last facility in the lower Colorado River with significant storage (Section 3.3). Releases from Parker Dam are made primarily to meet downstream water demands. Once released from Parker Dam, the flow is essentially unregulated until it reaches Imperial Dam.

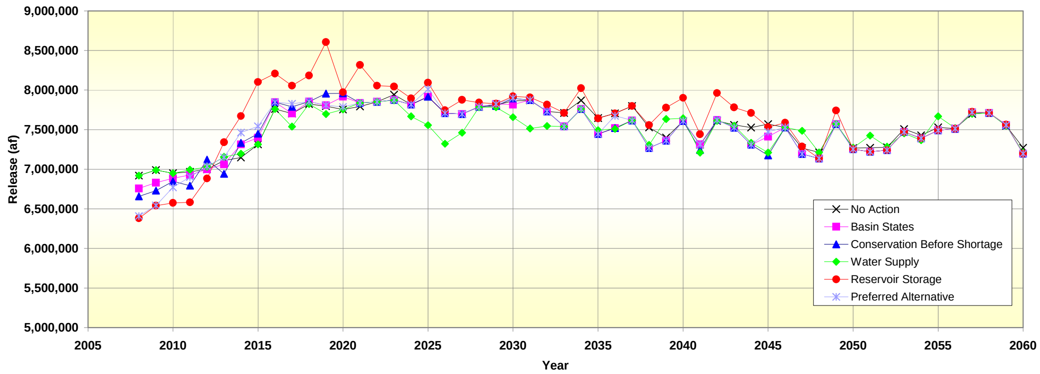
4.3.7.1 River Flows

The river flows in this reach are essentially the releases from Parker Dam. Releases greater than 7.0 maf generally correspond to years when flood flow releases are being made from Hoover Dam and these flows are passed through Davis Dam and Parker Dam. Releases less than 6.0 maf are generally associated with delivery reductions, which occur more frequently under the Conservation Before Shortage and Reservoir Storage Alternatives than under the No Action Alternative.

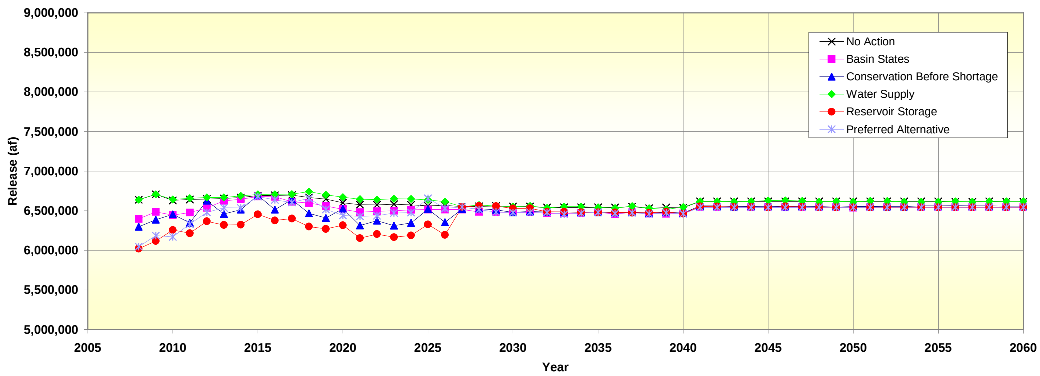
Figure 4.3-37 presents a comparison of the 90^{th}, 50^{th}, and 10^{th} percentile lines for Parker Dam annual releases under the action alternatives and the No Action Alternative. The 90^{th} percentile values represent releases due to flood control operations. The Reservoir Storage Alternative tends to release greater volumes during flood control when compared to the other alternatives since it keeps Lake Mead elevations higher. Beyond year 2045 all flow volumes converged to a release of about 7.40 maf. At the 50^{th} percentile, the Basin States, Conservation Before Shortage, and Reservoir Storage Alternatives, and the Preferred Alternative had less release volume than the No Action Alternative until the year 2026 due to a combination of the assumptions under each of those alternatives with regard to shortages and participation in the storage and delivery mechanism. The Water Supply Alternative generally released more volume over that same period. At year 2027, all alternatives converged to about 6.50 maf, with differences due to the assumption that SNWA would develop additional non-system water supplies that are permanent. The comparison of the 10^{th} percentile showed similar results that mirror the 50^{th} percentile values, except the release volumes were about 6.25 maf.

Figure 4.3-37
Parker Dam Annual Releases
Comparison of Action Alternatives to No Action Alternative
90th, 50th, and 10th Percentile Values

90th Percentile



50th Percentile



10th Percentile

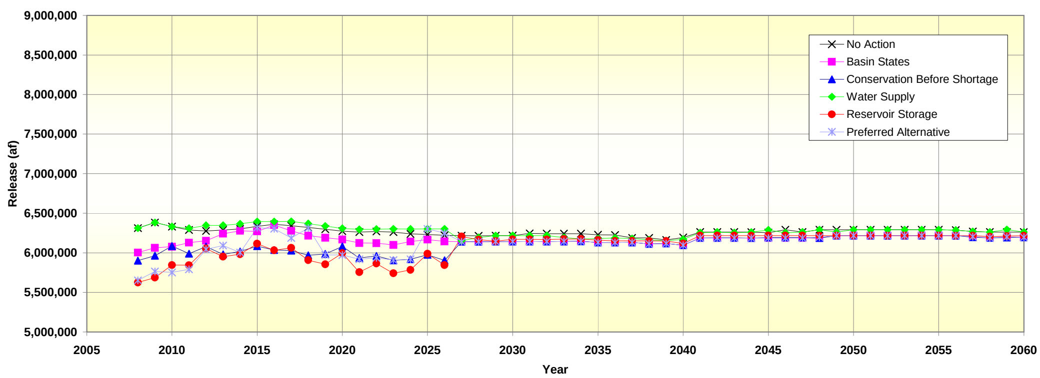


Figure 4.3-38 illustrates the cumulative distribution for Parker Dam annual releases for the interim period (2008 through 2026). The releases under the No Action Alternative range between 14.0 maf to 6.0 maf. The maximum annual releases under the action alternatives are similar to those of the No Action Alternative. The minimum annual release of 5.35 maf is observed under the Reservoir Storage Alternative. The Reservoir Storage Alternative generally provides the lowest annual releases while the Water Supply Alternative generally provides the highest annual releases of the action alternatives.

Figure 4.3-38
Parker Dam Cumulative Annual Releases
Comparison of Action Alternatives to No Action Alternative
Years 2008 through 2026

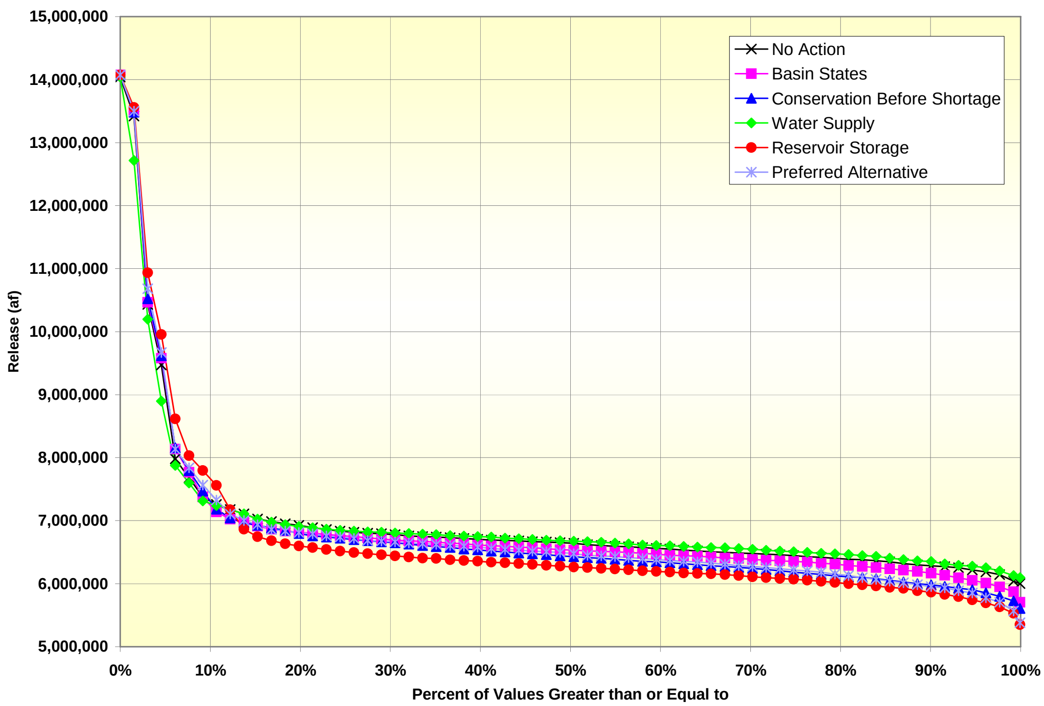
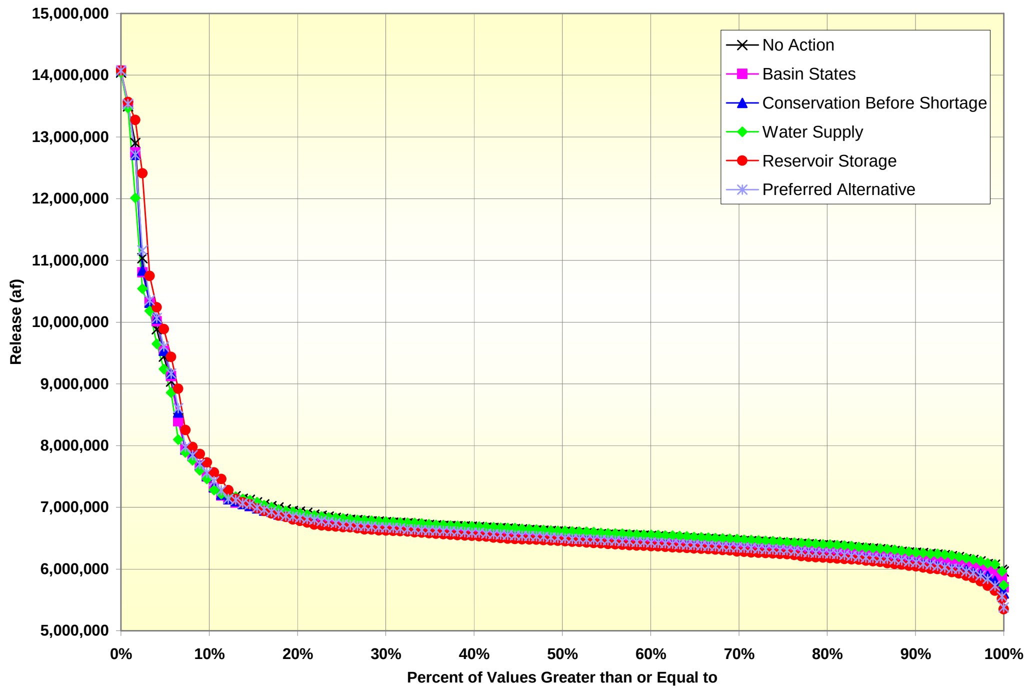


Figure 4.3-39 illustrates the cumulative distribution for the Parker Dam annual releases for the period of 2008 through 2060. The observed annual releases under all alternatives (including the No Action Alternative) fluctuate between approximately 14.0 maf to 5.35 maf. The lowest annual releases of 5.35 maf and 5.38 maf were observed under the Reservoir Storage Alternative and the Preferred Alternative, respectively.

Figure 4.3-39
Parker Dam Cumulative Annual Releases
Comparison of Action Alternatives to No Action Alternative
Years 2008 through 2060



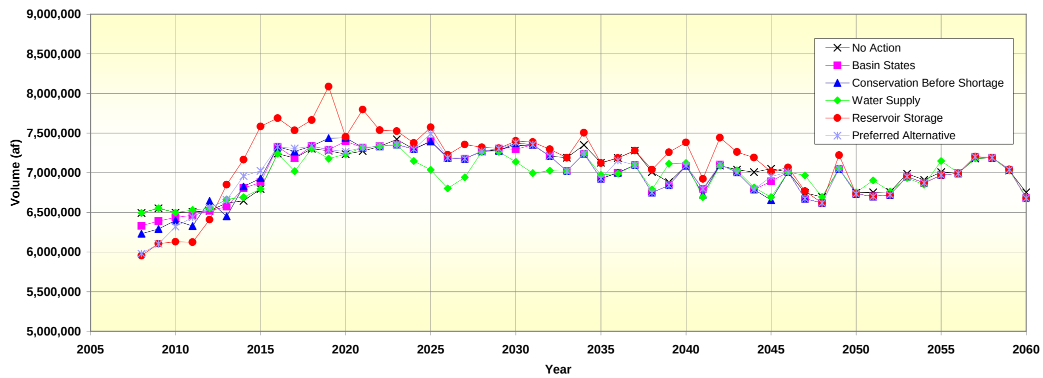
River Flows Near the Colorado River Indian Reservation. Two other points on the Colorado River were used to analyze flows in the reach between Parker Dam and Imperial Dam. These include a point located immediately upstream of the Colorado River Indian Reservation (CRIR) and a point located immediately 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 would be affected by delivery reductions to water users located downstream from this location.

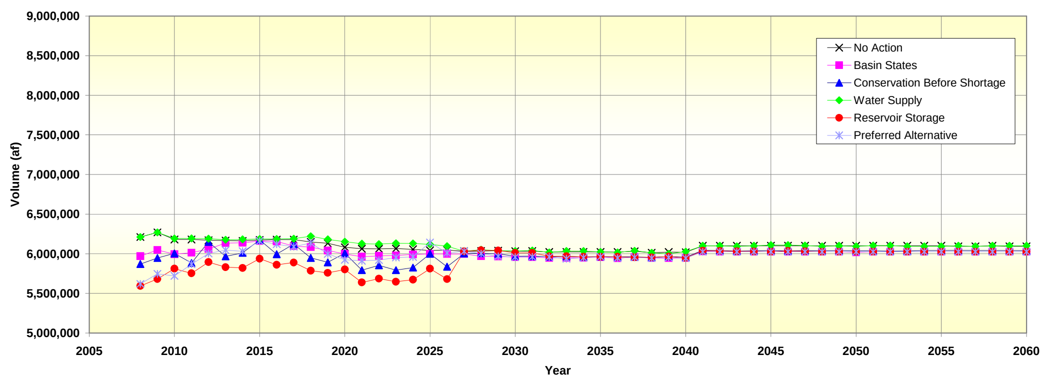
Figure 4.3-40 illustrates that the 90th, 50th, and 10th percentile annual flow values at this location generally reflect the releases from Parker Dam, as shown on Figure 4.3-38 and Figure 4.3-39. Since there is no significant storage capacity above Headgate Rock Dam, the differences between the flows at this location and the Parker Dam releases are due only to the attenuation of the flows that occurs in the 14 miles of river within this reach.

Figure 4.3-40
Colorado River Annual Flow Upstream of CRIR Diversion - RM 180.8
Comparison of Action Alternatives to No Action Alternative
90th, 50th, and 10th Percentile Values

90th Percentile



50th Percentile



10th Percentile

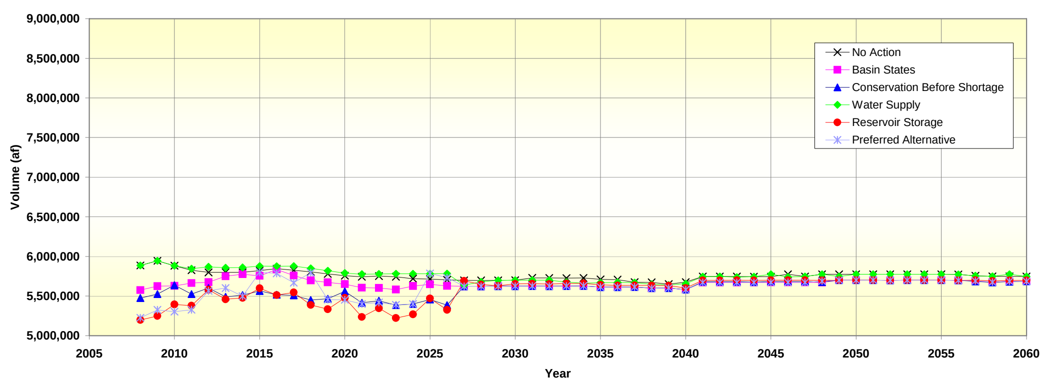


Table 4.3-34 provides a comparison of the 90th, 50th, and 10th percentile annual flow volumes upstream of the CRIR Diversion among the alternatives for selected years.

Table 4.3-34
Colorado River Annual Flow Upstream of CRIR Diversion - RM 180.8 (mafy)
Comparison of Action Alternatives to No Action Alternative
90th, 50th, and 10th Percentile Values

Alternative	Year 2016			Year 2026			Year 2040			Year 2060		
	90th	50th	10th	90th	50th	10th	90th	50th	10th	90th	50th	10th
No Action	7.242	6.177	5.845	7.188	6.048	5.703	7.089	6.019	5.676	6.753	6.093	5.746
Basin States	7.328	6.156	5.836	7.188	5.998	5.628	7.089	5.945	5.580	6.678	6.025	5.687
Conservation Before Shortage	7.328	5.993	5.517	7.188	5.837	5.386	7.089	5.956	5.582	6.678	6.040	5.686
Water Supply	7.242	6.187	5.876	6.802	6.094	5.782	7.123	6.026	5.655	6.693	6.100	5.746
Reservoir Storage	7.688	5.680	5.513	7.226	5.679	5.325	7.381	5.946	5.601	6.678	6.025	5.699
Preferred Alternative	7.328	6.119	5.787	7.188	6.009	5.733	7.089	5.944	5.580	6.678	6.025	5.686

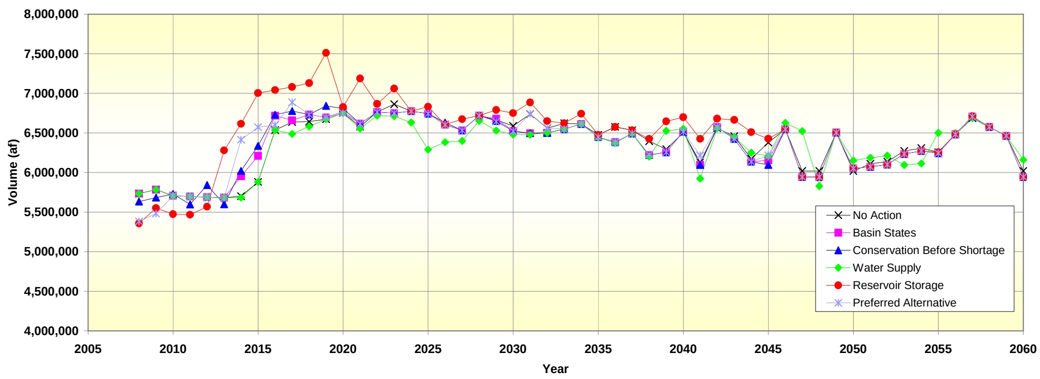
River Flows Downstream of the Palo Verde Diversion Dam. The flow of the Colorado River between Palo Verde Diversion Dam and Imperial Dam is normally the amount needed to meet both the consumptive use requirements in the United States downstream of the Palo Verde Diversion Dam and deliveries to Mexico. 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.

The 90th, 50th, and 10th percentile annual flow volumes for the Colorado River at this point are shown on Figure 4.3-41. The greatest variability between alternatives occurs during the interim period (2008 through 2026). After 2026, the action alternatives converge to the No Action Alternative.

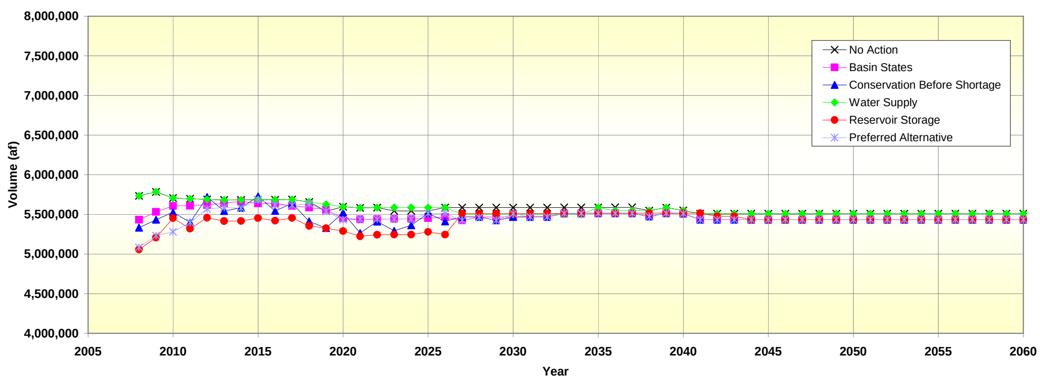
The 90th percentile flow volumes for the action alternatives were generally similar to those of the No Action Alternative, although there was some variability observed under the Water Supply and Reservoir Storage Alternatives. The greatest variability occurs during the interim period and reflects the difference in the assumptions with regard to shortage and water conservation. The 50th percentile annual flow volumes for all alternatives are generally similar with the Reservoir Storage Alternative having the lowest values. At the 10th percentile level, the Water Supply Alternative shows slightly higher flow volumes compared to the No Action Alternative. The Basin States, Conservation Before Shortage, and Reservoir Storage Alternatives, and the Preferred Alternative show progressively lower flow volumes than the No Action Alternative.

Figure 4.3-41
Colorado River Annual Flow Downstream of Palo Verde Diversion Dam - RM 133.8
Comparison of Action Alternatives to No Action Alternative
90th, 50th, and 10th Percentile Values

90th Percentile



50th Percentile



10th Percentile

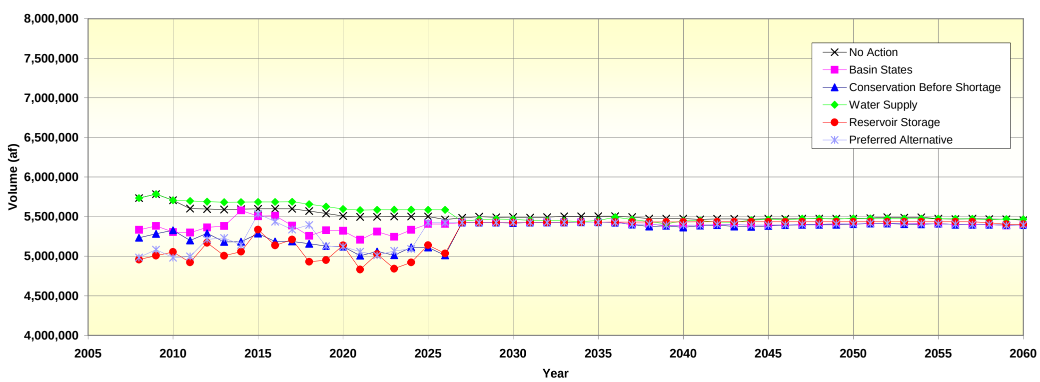


Table 4.3-35 provides a comparison of the 90th, 50th, and 10th percentile annual flow volumes downstream of the Palo Verde Diversion Dam.

Table 4.3-35
Colorado River Annual Flow Downstream of Palo Verde Diversion Dam - RM 133.8 (mafy)
Comparison of Action Alternatives to No Action Alternative
90th, 50th, and 10th Percentile Values

Alternative	Year 2016			Year 2026			Year 2040			Year 2060		
	90th	50th	10th	90th	50th	10th	90th	50th	10th	90th	50th	10th
No Action	6.536	5.685	5.598	6.605	5.586	5.463	6.506	5.549	5.475	6.019	5.509	5.455
Basin States	6.717	5.639	5.510	6.602	5.465	5.406	6.516	5.510	5.388	5.944	5.434	5.393
Conservation Before Shortage	6.730	5.544	5.185	6.631	5.411	5.011	6.516	5.510	5.363	5.944	5.434	5.393
Water Supply	6.536	5.685	5.685	6.382	5.586	5.586	6.550	5.549	5.446	6.160	5.509	5.466
Reservoir Storage	7.041	5.419	5.137	6.605	5.244	5.034	6.699	5.514	5.432	5.943	5.434	5.403
Preferred Alternative	6.598	5.616	5.435	6.602	5.511	5.423	6.516	5.510	5.392	5.944	5.434	5.393

4.3.7.2 Groundwater

Flows in the Parker Dam to Imperial Dam reach are primarily composed of water released from Parker Dam and therefore, the annual median releases are representative of the annual median flows in each reach (Section 3.3). When converted to stage, a comparison of the annual median releases for each alternative may be used as the indicator to analyze potential effects to groundwater adjacent to the river in this reach.

Figure 4.3-42 illustrates the annual median releases from Parker Dam for the action alternatives and the No Action Alternative for 2008 through 2060. As was the case for the Davis Dam releases, the median releases for the Water Supply and Reservoir Storage Alternatives bracket the median releases for the other four alternatives due primarily to the different shortage assumptions for each of the alternatives. Table 4.3-36 compares the annual median values of the action alternatives relative to the No Action Alternative for specific years (each action alternative value less the No Action Alternative value). Using appropriate relationships to convert flow-to-stage (LCR MSCP BA, Appendix J, Attachment D), these relative flow differences would result in minor reductions in river stage (on the order of 0.25 feet). Based on the relationships used in the LCR MSCP BA, Appendix K, such river stage reductions would result in corresponding reductions in groundwater elevations adjacent to the river (approximately 0.15 feet to 0.30 feet reduction for gaining and losing reaches, respectively).

Figure 4.3-42
Parker Dam Annual Releases
Comparison of Action Alternatives to No Action Alternative
Annual Median (50th Percentile) Values

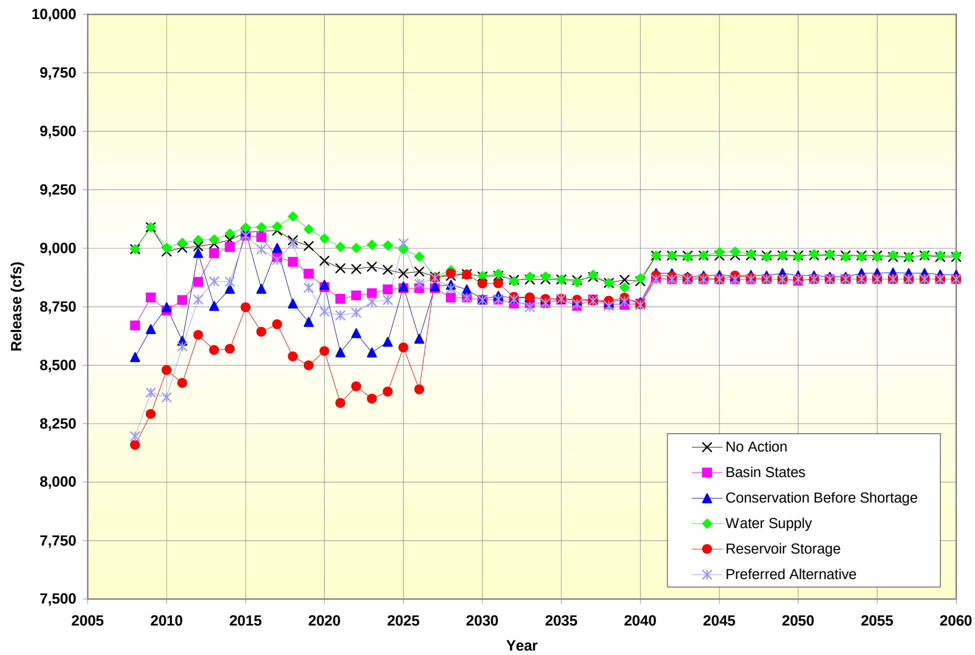


Table 4.3-36
Parker Dam Annual Median Releases
Differences of Action Alternatives Compared to No Action Alternative[1], (cfs)

Year	Basin States	Conservation Before Shortage	Water Supply	Reservoir Storage	Preferred Alternative
2008	(327)	(462)	0	(837)	(801)
2011	(224)	(398)	21	(578)	(422)
2016	(25)	(246)	17	(430)	(78)
2017	(114)	(75)	17	(401)	(126)
2026	(72)	(288)	64	(504)	(52)
2027	(50)	(420)	(1)	(6)	(6)
2040	(96)	(90)	13	(99)	(102)
2060	(95)	(76)	7	(95)	(95)

1 Value of the action alternative minus the value from the No Action Alternative provides the difference shown. Values shown in parenthesis indicate that the value under the action alternative is lower than that of the No Action Alternative, i.e. a flow reduction.

4.3.8 Imperial Dam to NIB

Most of the water delivered to Mexico is diverted at Imperial Dam, conveyed via the AAC, 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 (Section 3.3). The proposed federal action will not alter the operation of these diversions and wasteways and therefore, will not have an effect on this river reach.

4.3.9 NIB to SIB

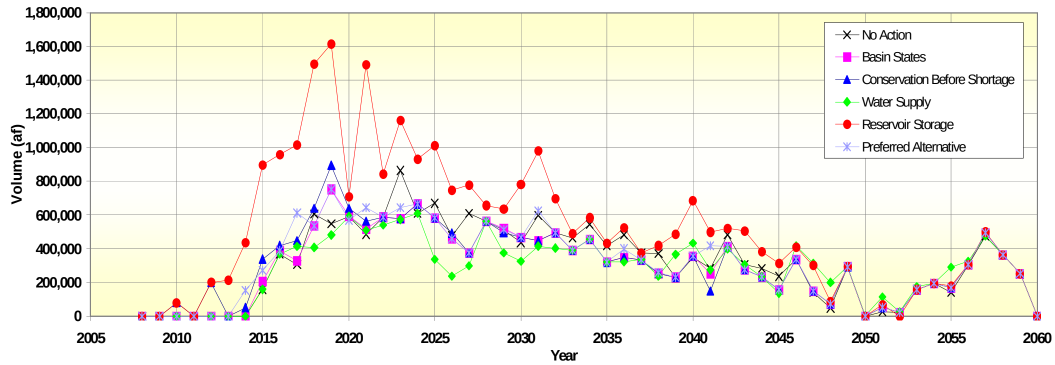
Mexico diverts most of its Colorado River water supply at the Morelos Diversion Dam, and except during flood control operations, only limited flows actually pass Morelos Diversion Dam (Section 3.3). During flood control operations, releases are made from Hoover Dam as dictated by the flood control criteria established with the USACE (Section 3.3). These releases are dependent upon the amount of available storage in the system (including Lake Powell and Lake Mead) and the hydrologic inflow forecast. The proposed federal action could potentially change the volume of water in storage in Lake Powell and Lake Mead, thereby affecting the frequency and/or volume of flood control releases.

In addition, the modeling assumptions used to model the storage and delivery mechanism for the Conservation Before Shortage and Reservoir Storage Alternatives could potentially alter the flows in this reach. It was assumed that water conservation activities in Mexico would result in conserved water that would be stored in Lake Mead and delivered on a periodic basis to Mexico through the NIB to the SIB reach. These modeling assumptions (described in Appendix M) were used in this Final EIS in order to analyze the potential impacts to resources of the storage and delivery mechanism, particularly with regard to reservoir elevations and river flow impacts. The use of these modeling assumptions does not represent any determination by Reclamation as to whether, or how, any storage/delivery arrangements would actually be implemented in the future. These modeling assumptions are not intended to constitute an interpretation or application of the 1944 Treaty or to represent current United States policy or a determination of future United States policy regarding deliveries to Mexico. Details of these assumptions are discussed in Section 4.2 and Appendix M.

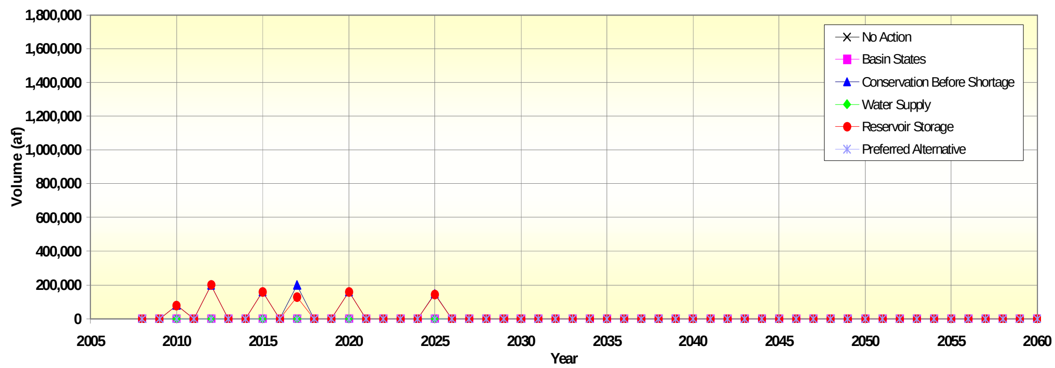
The 90th, 50th, and 10th percentile annual flow volumes for this reach are shown in Figure 4.3-43.

Figure 4.3-43
Colorado River Annual Flow Below Mexico Diversion at Morelos Diversion Dam - RM 21.1
Comparison of Action Alternatives to No Action Alternative
90th, 50th, and 10th Percentile Values

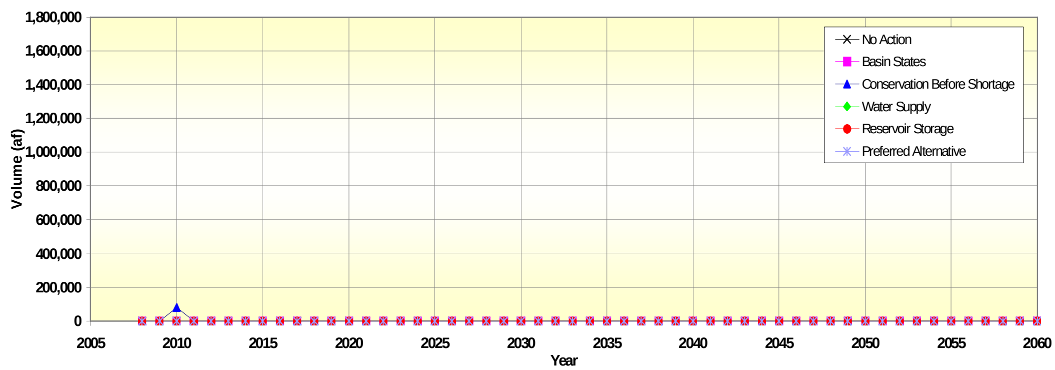
90th Percentile



50th Percentile



10th Percentile



Flows at the 90th percentile are produced by flood control operations. The values for the Reservoir Storage Alternative were generally greater than for the other alternatives due to higher reservoir levels. After 2048, the 90th percentile annual flow volumes are all similar. The 90th percentile annual flow volumes for the Water Supply Alternative were generally lower than the other alternatives through about 2030, whereas the volumes for the Reservoir Storage Alternative were higher through about 2045. Flows at the 50th percentile are comprised solely of non-flood control flows. The Basin States and Water Supply alternatives, and the No Action Alternative assume no activity with regard to delivery of conserved water to Mexico. The 50th percentile flows for the Conservation Before Shortage and Reservoir Storage Alternatives show intermittent annual flow volumes of from about 40 kaf to 200 kaf during the interim period. At the 10th percentile, the Conservation Before Shortage is the only alternative that shows an annual flow value that is greater than zero, in the year 2010 at a volume of 80 kaf.

Table 4.3-37 provides a comparison of the 90th, 50th, and 10th percentile annual flow volumes below the Mexico diversion at Morelos Diversion Dam between the action alternatives and No Action Alternative for selected years.

Table 4.3-37
Colorado River Annual Flow Below Mexico Diversion at Morelos Diversion Dam - RM 21.1 (maf)
Comparison of Action Alternatives to No Action Alternative
90th, 50th, and 10th Percentile Values

Alternative	Year 2016			Year 2026			Year 2040			Year 2060		
	90th	50th	10th	90th	50th	10th	90th	50th	10th	90th	50th	10th
No Action	0.367	0.000	0.000	0.477	0.000	0.000	0.347	0.000	0.000	0.000	0.000	0.000
Basin States	0.388	0.000	0.000	0.459	0.000	0.000	0.355	0.000	0.000	0.000	0.000	0.000
Conservation Before Shortage	0.418	0.000	0.000	0.493	0.000	0.000	0.355	0.000	0.000	0.000	0.000	0.000
Water Supply	0.367	0.000	0.000	0.237	0.000	0.000	0.432	0.000	0.000	0.000	0.000	0.000
Reservoir Storage	0.957	0.000	0.000	0.747	0.000	0.000	0.686	0.000	0.000	0.000	0.000	0.000
Preferred Alternative	0.388	0.000	0.000	0.459	0.000	0.000	0.355	0.000	0.000	0.000	0.000	0.000

Figure 4.3-44 shows the cumulative distribution for annual volumes of excess flows occurring below the Mexico diversion at the Morelos Diversion Dam for the interim period (2008 through 2026). At flows less than about 250 kaf, the differences are mostly due to the assumed delivery of conserved water to Mexico under the Conservation Before Shortage and Reservoir Storage Alternatives. Flows greater than about 250 kaf are the result of flood control operations at Lake Mead. As shown in Figure 4.3-44, the probability of excess flows of any magnitude under the No Action Alternative, Preferred Alternative, and the Basin States and Water Supply alternatives during the interim period are approximately nine to ten percent. The probability of excess flows of any magnitude under the Conservation Before Shortage and Reservoir Storage Alternatives are 33 and 30 percent, respectively.

Figure 4.3-44
Excess Flows Below Mexico Diversion at Morelos Diversion Dam
Comparison of Action Alternatives to No Action Alternative
Cumulative Distribution - Years 2008 through 2026

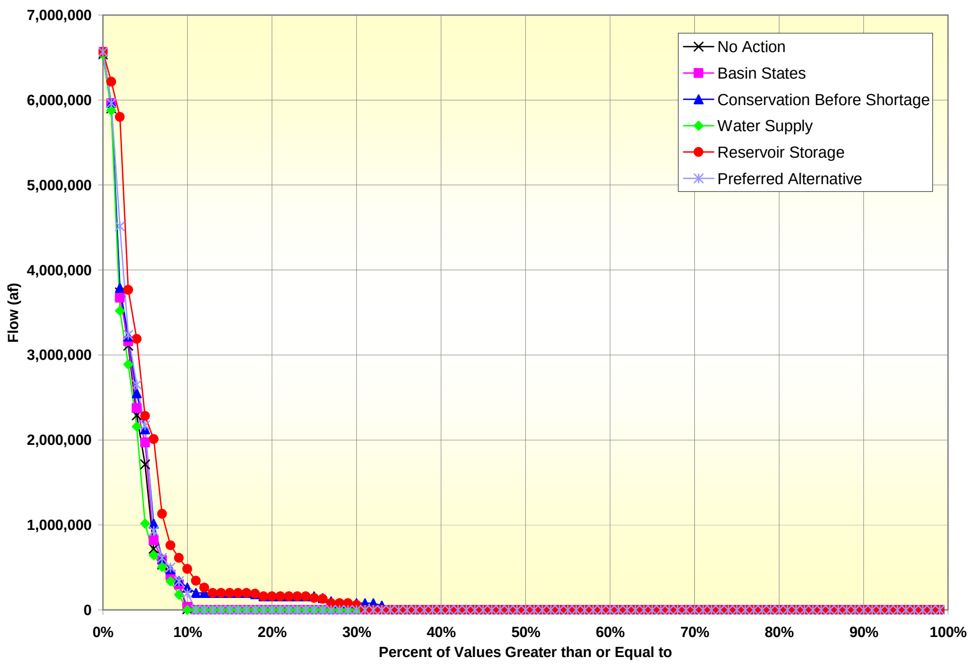
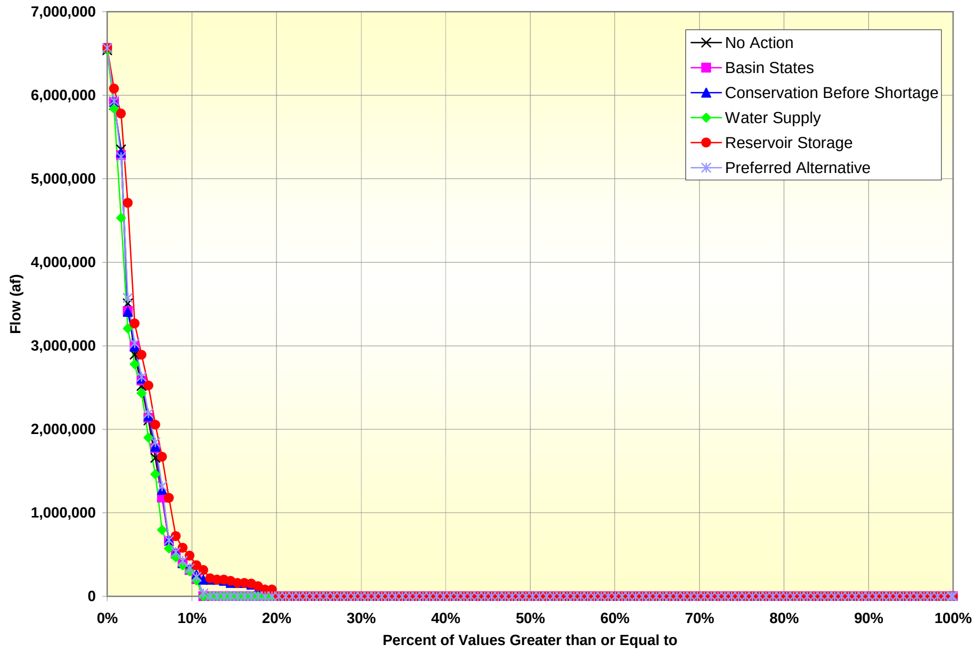


Figure 4.3-45 shows the cumulative distribution for annual volumes of excess flows below the Mexico diversion at Morelos Diversion Dam for the period between 2008 through 2060. Again, flows less than about 250 kaf are due to the assumed delivery of conserved water to Mexico under the Conservation Before Shortage and Reservoir Storage Alternatives and occur during the interim period only.

Figure 4.3-45
Excess Flows Below Mexico Diversion at Morelos Diversion Dam
Comparison of Action Alternatives to No Action Alternative
Cumulative Distribution - Years 2008 through 2060



4.3.10 Summary

The following conclusions were drawn from the analyses of hydrologic resources.

4.3.10.1 Reservoir Storage

The Water Supply Alternative generally provides lower Lake Powell elevations than the No Action Alternative. Conversely, the Reservoir Storage Alternative provides higher Lake Powell elevations than the No Action Alternative. The observed Lake Powell elevations under the Basin States and Conservation Before Shortage Alternatives, and the Preferred Alternative are similar to each other because these action alternatives assume the same operation at Lake Powell. The 50th and 10th percentile values of these three alternatives vary less than those of the Water Supply and Reservoir Storage Alternatives. The greatest difference in Lake Powell elevation between the Basin States and Conservation Before Shortage Alternatives, and the Preferred Alternative relative to the No Action Alternative in any one year is about 33 feet occurring at the 10th percentile.

The Lake Mead 50th percentile elevations under the Water Supply Alternative are generally lower than those under the No Action Alternative. However, the Lake Mead 10th percentile elevations under the Water Supply Alternative vary and are sometimes higher and sometimes lower than those under the No Action Alternative. These fluctuations are due to balancing releases from Lake Powell that are greater than releases under the No Action Alternative (resulting in higher Lake Mead elevations) and shortage amounts that are less than those in the No Action Alternative (resulting in lower Lake Mead elevations). The Reservoir Storage Alternative generally provides higher Lake Mead elevations than the No Action Alternative. The observed Lake Mead elevations under the Basin States and Conservation Before Shortage Alternatives, and the Preferred Alternative are similar to each other because these alternatives assume the same operation at Lake Powell and the same release reductions corresponding to the same Lake Mead elevations. The 50th and 10th percentile values of these three alternatives vary less than those of the Water Supply and Reservoir Storage Alternatives. Both the 50th and 10th percentile values of the Basin States and Conservation Before Shortage Alternatives, and the Preferred Alternative vary from being higher and sometimes lower than those of the No Action Alternative.

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 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.

4.3.10.2 Reservoir Releases

During the interim period (2008 through 2026), Glen Canyon Dam releases less than the annual minimum objective release of 8.23 maf occurred less than one percent of the time under the No Action Alternative, approximately ten percent of the time under the Basin States, Conservation Before Shortage, and Water Supply alternatives, and the Preferred Alternative, and approximately 17 percent of the time under the Reservoir Storage Alternative. Over the interim period, releases greater than the annual minimum objective release of 8.23 maf occurred approximately 42 percent of the time under the No Action Alternative, approximately 62 percent of the time under the Basin States and Conservation Before Shortage Alternatives, 69 percent of the time under the Water Supply Alternative, 44 percent of the time under the Reservoir Storage Alternative, and 59 percent of the time under the Preferred Alternative.

During the interim period (2008 through 2026), the observed minimum and maximum Hoover Dam annual releases under the No Action Alternative are 7.46 maf and 17.13 maf, respectively. By comparison, the minimum annual release under the action alternatives is 7.3 maf and occurs under the Conservation Before Shortage Alternative. The maximum annual release of 17.16 maf occurs under the Basin States, Conservation Before Shortage, and Reservoir Storage Alternatives, and the Preferred Alternative. In general, the annual release volumes under the Basin States, Conservation Before Shortage, and Reservoir Storage Alternatives, and the Preferred Alternative are similar to those under the No Action Alternative. The Hoover Dam annual releases under the Water Supply Alternative are generally higher than under the No Action Alternative. The Hoover Dam annual releases under the Reservoir Storage Alternative are generally lower than under the No Action Alternative.

The releases from Davis Dam and Parker Dam generally reflect the same pattern of releases under the different action alternatives as those from Hoover Dam. The differences in the release volumes are mostly attributed to the depletions that occur upstream of each respective dam.

4.3.10.3 River Flows

The river flows that occur between Glen Canyon Dam and Lake Mead result mostly from controlled releases from Glen Canyon Dam. Since the gains from tributaries in this reach on average are less than three percent of the total flow and would not be affected by the proposed federal action, the relative comparison of annual river flows would be essentially the same as the comparison made for the annual releases from Glen Canyon Dam. Daily and hourly releases from Glen Canyon Dam would continue to be made consistent with the 1996 Grand Canyon ROD pending the outcome of the long-term experiment program.

The river flows that occur downstream of Hoover Dam also result mostly from controlled releases from Hoover, Davis, and Parker dams. For all reaches, the projected river flows are bound by the Water Supply Alternative (at the high end) and the Reservoir Storage Alternative (at the low end). Differences in river flows for each alternative relative to this No Action Alternative are small (less than 1 percent).

4.3.10.4 Groundwater

The river flow reductions were determined to have no effect on the groundwater resources within the river reach that extends from Glen Canyon Dam to Lake Mead. The river flow reductions that occur below Hoover Dam could potentially affect groundwater resources within the different river reaches where they occur. However, the potential changes in median flows, river stage reductions, and corresponding potential effects on groundwater elevations relative to the No Action Alternative were shown to be small (less than 0.5 feet).

4.4 Water Deliveries

This section compares water deliveries from the Colorado River mainstream to the Lower Division states and Mexico under the No Action Alternative and the action alternatives. In addition, potential impacts of shortages to water user categories (agricultural, M&I, and Tribal) within Arizona are compared. The allocation of shortages to California and Nevada generally affect single entities within each state (MWD in California and SNWA in Nevada) and therefore analyses of potential impacts to other Colorado River water users within these two states were not performed. Additional details with regard to potential shortages to specific water users within each Lower Division state are presented in Appendix G.

4.4.1 Methodology

The methodology used to analyze total water deliveries to each Lower Division state and Mexico for each alternative is based on the hydrologic model CRSS described in Section 4.2 and in Appendix A. Modeling assumptions with respect to the distribution of shortages and related water delivery reductions to the Lower Division states and Mexico are summarized in Section 2.2 and Section 4.2.

4.4.1.1 Shortage Allocation Model

To analyze the potential impacts of shortages to water users within each Lower Division state, a more detailed model, the Shortage Allocation Model, was developed. The Shortage Allocation Model was used to estimate delivery of water to Colorado River water entitlement holders within the Lower Division states under varying levels of shortages. The entitlements, along with consumptive use schedules and established priorities within each Lower Division state, were included as parameters in the Shortage Allocation Model. In addition, the shortage distribution within the CAP is consistent with the Arizona Water Settlements Act (AWSA).

The Shortage Allocation Model allocates shortages to the Lower Division states consistent with the shortage sharing assumptions used in the CRSS model. The Shortage Allocation Model then distributes Colorado River water to entitlement holders within each state based on the priority of water rights within each respective state using the assumption that shortages will be shared on a pro-rata basis by users of the same priority. Within Arizona, certain modeling assumptions were adjusted between the Draft EIS and the Final EIS based on information received from the ADWR during the public comment period. A detailed description of the Shortage Allocation Model and the methodologies used to distribute the shortages is provided in Appendix G. A list of each Lower Division state's Colorado River water entitlement holders, listed by priority, is included in Appendix E.

Total Lower Basin shortages of 100 kaf to 2.5 maf (in increments of 100 kaf) were analyzed in the Shortage Allocation Model, covering the range of total Lower Basin shortages projected to occur under the No Action Alternative and the action alternatives[1]. The output for each model run shows how shortages were distributed to each entitlement holder within each state. The Shortage Allocation Model also summarized shortages into three water user categories in Arizona (agricultural, M&I, and Tribal), which are presented in Section 4.4.5. Detailed output from the Shortage Allocation Model is provided in Appendix G.

4.4.2 Apportionments to the Upper Division States

The proposed federal action will not affect the apportionments to the Upper Division states nor their ability to use their Compact apportionments. Therefore no resource impact analysis was considered necessary.

4.4.3 Apportionments to the Lower Division States and Water Entitlements within Each State

The proposed federal action will not affect the apportionments to the Lower Division states or the water entitlements to water users within those states and therefore no resource impact analysis was considered necessary. However, water deliveries to each state and to users within each state may be affected and are analyzed in the following sections.

4.4.4 Lower Division States Water Supply Determination

The proposed federal action would provide guidance to the Secretary's annual determination of the water supply condition (Surplus, Normal, or Shortage) for the Lower Division states. This section compares the probabilities of the determinations that would be made under each alternative.

4.4.4.1 Shortage Conditions

A Shortage Condition exists in a particular year when the Secretary determines that there is insufficient mainstream water available to satisfy the 7.5 maf of consumptive use in the Lower Division states. The elements of the proposed federal action include shortage guidelines and each alternative assumes a specific formulation for determining a Shortage Condition (Chapter 2).

[1] As a result of updating the CRSS initial conditions to reflect the June 2007 projections of January 1, 2008 reservoir contents, water delivery reductions with volumes greater than 2.5 maf were observed in four out of 100 hydrologic sequences under the Water Supply Alternative and only in year 2027. These shortage volumes were primarily the result of the assumption that operations would revert back to the assumptions made under the No Action Alternative after the interim period. Consequently, analysis of shortages greater than 2.5 maf in the Final EIS was not considered necessary due to their low probability of occurrence.

Probability of Involuntary and Voluntary Shortage. The Conservation Before Shortage proposal suggested an approach to the management of shortages in the Lower Basin whereby voluntary water delivery reductions would occur at specific Lake Mead elevations in order to delay the onset of larger, involuntary water reductions. The voluntary water reductions would occur through a compensation program whereby willing Lower Basin Colorado River water users, including Mexico, would be paid to voluntarily and temporarily reduce their water use (Section 2.4). Conversely, involuntary water delivery reductions might be imposed by the Secretary through the determination of a Shortage Condition pursuant to Article II(B)(3) of the Consolidated Decree.

Although the mechanism for voluntary and involuntary water delivery reductions would be different, the potential hydrologic impacts of voluntary or involuntary shortages would be the same. Similarly, the potential impacts to other environmental resources would be the same with the possible exception of socioeconomic impacts (Section 4.14). In this and in subsequent sections of the Final EIS, voluntary water delivery reductions proposed by the Conservation Before Shortage Alternative are termed “voluntary shortages”, and involuntary water delivery reductions imposed by a Secretarial determination of a Shortage Condition are termed “involuntary shortages”. Voluntary and involuntary shortages are analyzed separately or together in subsequent analyses as appropriate.

The probability of the determination of a Shortage Condition and associated involuntary shortages for all alternatives is illustrated in Figure 4.4-1. Under the No Action Alternative, the probability of involuntary shortage increases throughout the interim period from four percent in 2010 to about 50 percent in 2026. All action alternatives have lower probabilities of involuntary shortage when compared to the No Action Alternative from 2013 through 2026, with the Water Supply and Conservation Before Shortage Alternatives showing the lowest probabilities. Table 4.4-1 provides a comparison of the alternatives with respect to the first year of involuntary shortage and the probability of occurrence. Table 4.4-2 provides the probability of any amount of involuntary Lower Basin shortage for specific years.

The Conservation Before Shortage and Water Supply alternatives result in relatively infrequent, involuntary shortages during the interim period due to quite different reasons. The Conservation Before Shortage Alternative assumes that voluntary shortages would occur prior to the onset of involuntary shortages, whereas the Water Supply Alternative imposes involuntary shortages only if Lake Mead storage approaches the top of the dead pool elevation or when Lake Mead’s elevation falls below 1,000 feet msl (the current limit of SNWA’s lower intake). Figure 4.4-1 shows that the probability of involuntary shortages ranges from zero to 12 percent over the interim period for the Water Supply Alternative. Figure 4.4-1 also shows that the probability of involuntary shortages under the Conservation Before Shortage Alternative is similar (approximately zero to nine percent over the interim period) since involuntary shortages are imposed under that alternative only to protect Lake Mead from falling below elevation 1,000 feet msl.

Figure 4.4-1
Involuntary Lower Basin Shortages
Comparison of Action Alternatives to No Action Alternative
Probability of Occurrence of Any Involuntary Shortage Volume

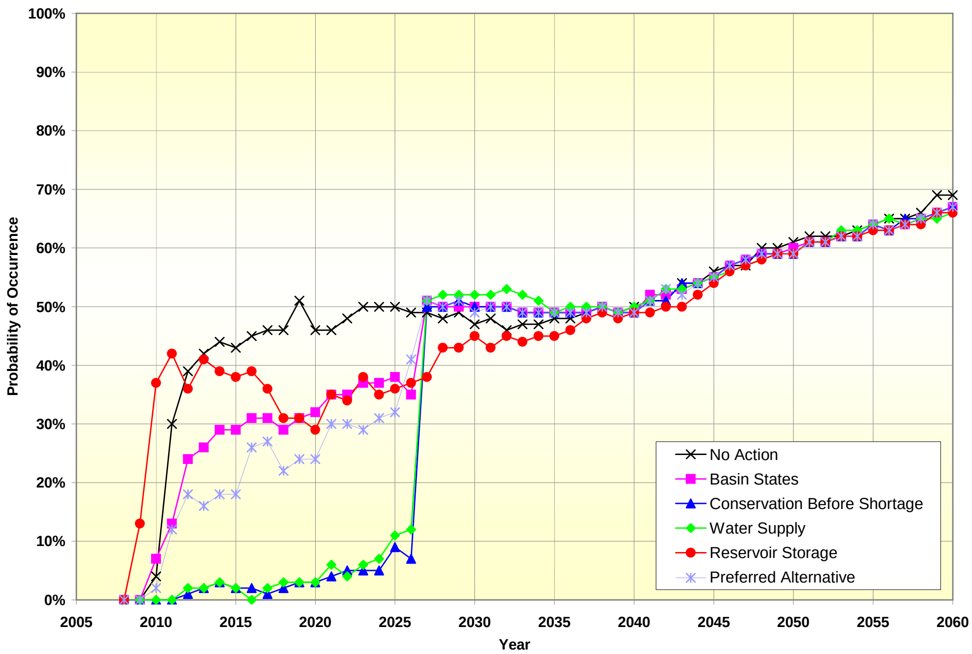


Table 4.4-1
First Year of Involuntary Shortage and Probability of Occurrence
Comparison of Action Alternatives to No Action Alternative

Alternative	No Action	Basin States	Conservation Before Shortage	Water Supply	Reservoir Storage	Preferred Alternative
Year	2010	2010	2012	2012	2009	2010
Probability (%)	4	7	1	2	13	2

Table 4.4-2
Probability of Occurrence of Any Amount of Involuntary Shortage for Specific Years (percent)
Comparison of Action Alternatives to No Action Alternative

Year	No Action	Basin States	Conservation Before Shortage	Water Supply	Reservoir Storage	Preferred Alternative
2008	0	0	0	0	0	0
2017	46	31	1	2	36	27
2026	49	35	7	12	37	41
2027	49	51	50	51	38	51
2040	50	49	49	50	49	49
2060	69	67	67	66	66	67

Figure 4.4-2, Table 4.4-3, and Table 4.4-4 present comparisons for all alternatives when both involuntary and voluntary shortages are considered. When both involuntary and voluntary shortages are considered, the occurrence of the first shortage in 2010 is identical for the Basin States and Conservation Before Shortage Alternatives, and the Preferred Alternative. The probability of shortages in 2010 differs (seven percent, four percent, and two percent for the Basin States Alternative, Conservation Before Shortage Alternative, and the Preferred Alternative, respectively) due to the different assumptions with regard to the participation in the storage and delivery mechanism for those alternatives. The Preferred Alternative also shows lower probabilities (up to approximately ten percent) of voluntary and involuntary shortage over the entire interim period when compared to the Basin States and Conservation Before Shortage Alternatives.

Figure 4.4-2
Involuntary and Voluntary Lower Basin Shortages
Comparison of Action Alternatives to No Action Alternative
Probability of Occurrence of Any Shortage Volume

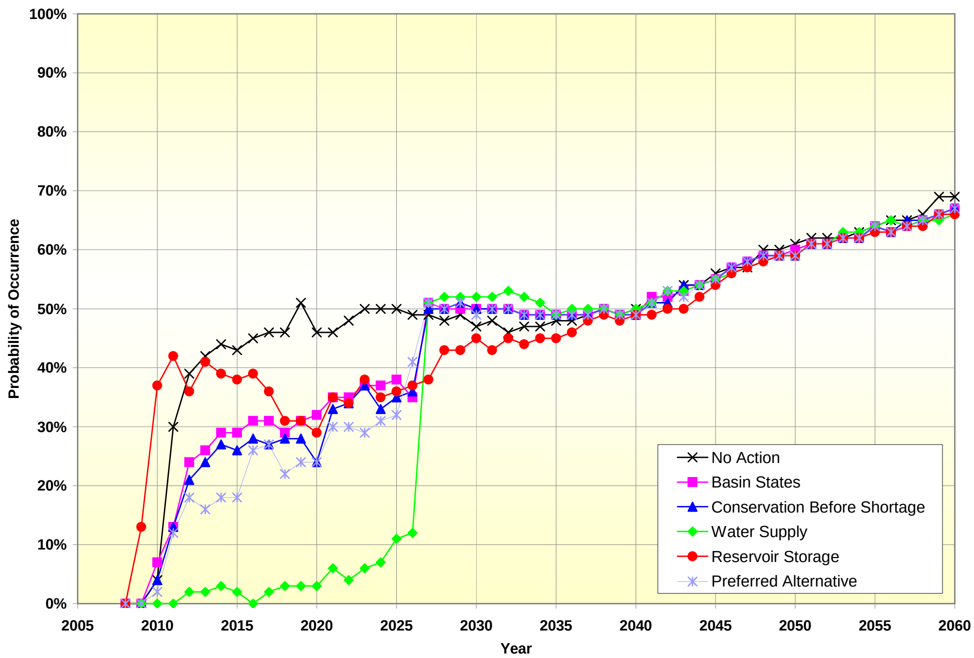


Table 4.4-3
First Year of Involuntary or Voluntary Shortage and Probability of Occurrence
Comparison of Action Alternatives to No Action Alternative

Alternative	No Action	Basin States	Conservation Before Shortage	Water Supply	Reservoir Storage	Preferred Alternative
Year	2010	2010	2010	2012	2009	2010
Probability (%)	4	7	4	2	13	2

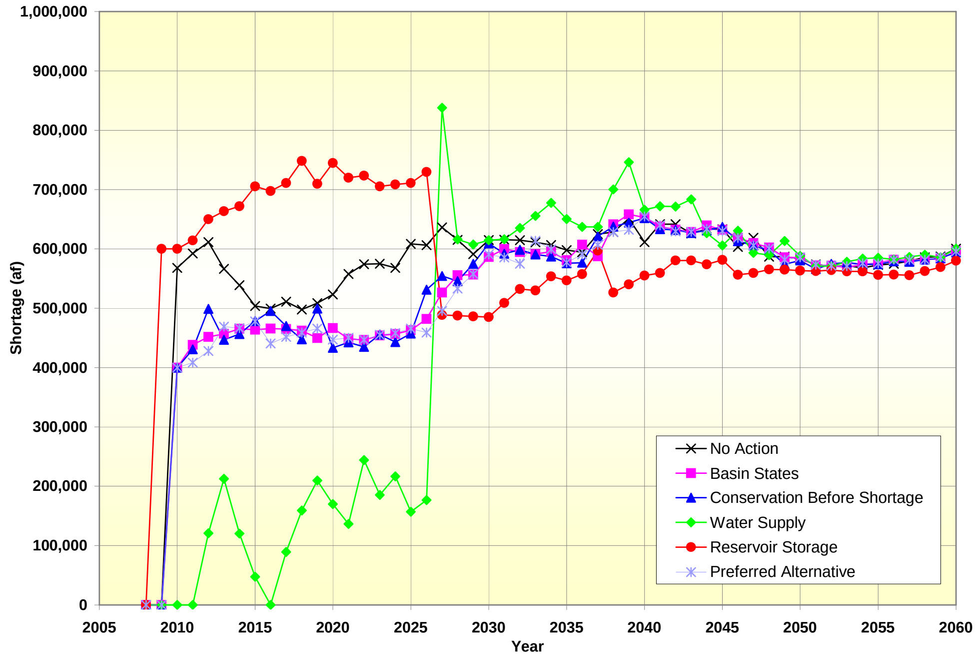
Table 4.4-4
Probability of Occurrence of Involuntary and Voluntary Shortages of Any Amount for Specific Years (percent)
Comparison of Action Alternatives to No Action Alternative

Year	No Action	Basin States	Conservation Before Shortage	Water Supply	Reservoir Storage	Preferred Alternative
2008	0	0	0	0	0	0
2017	46	31	27	2	36	27
2026	49	35	36	12	37	41
2027	49	51	50	51	38	51
2040	50	49	49	50	49	49
2060	69	67	67	66	66	67

Magnitude of Involuntary and Voluntary Shortages. Although the probability of a shortage occurring is an important factor, the magnitude of the shortage is also important. Each alternative has specific assumptions with regard to when and by how much deliveries would be reduced.

The average shortage volumes for each year provide a weighted measure that considers both the frequency and magnitude of the potential shortages. The average shortage volumes for each year are calculated by multiplying the observed volumes of shortages by their respective frequency of occurrence and summing those values (or alternatively, by simply summing the shortages for all traces and dividing by the total number of traces). A comparison of the average shortage volumes (of both involuntary and voluntary shortages) under the action alternatives to those of the No Action Alternative is provided in Figure 4.4-3.

Figure 4.4-3
Involuntary and Voluntary Lower Basin Shortage
Comparison of Action Alternatives to No Action Alternative
Average Shortage Volumes

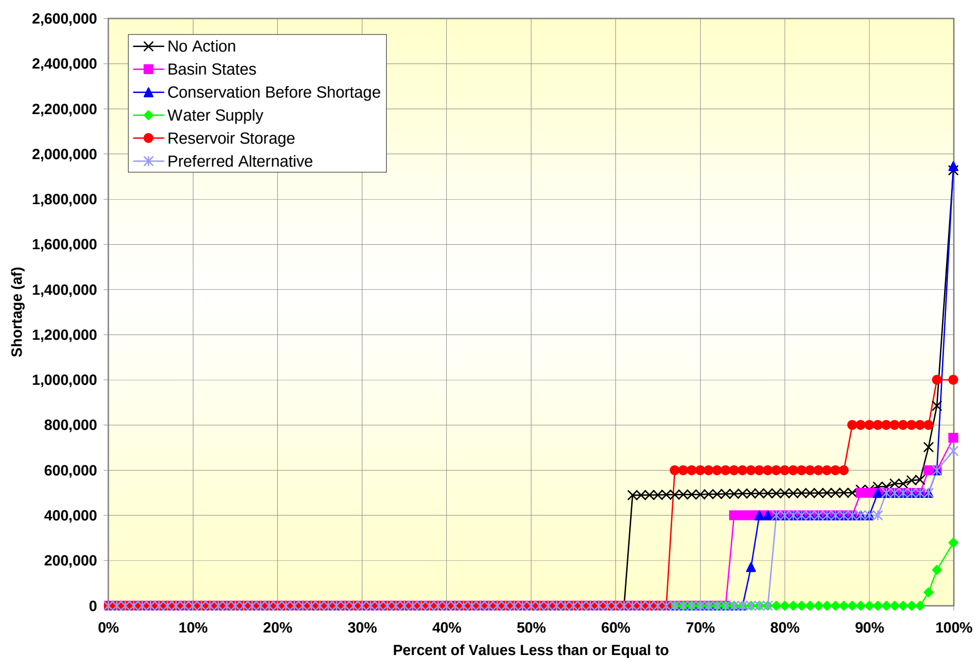


The average shortage volumes under the No Action Alternative from 2010 (the year of first shortage occurrence) through the interim period range between about 500 and 610 kafy and are reflective of the occurrence of the more frequent shortages which are on the order of 400 to 500 kafy based on Lake Mead trigger elevations (Section 2.2) as well as infrequent but larger shortages (on the order of 800 kafy to 2,000 kafy) necessary to keep Lake Mead above elevation 1,000 feet msl. The average shortages volume under the Water Supply Alternative from 2012 (the year of first shortage occurrence) through the interim period are between zero and 240 kafy and are indicative of the strategy which essentially determines no shortage except when Lake Mead elevation approaches the top of the dead pool elevation or is below 1,000 feet msl and there is no delivery to SNWA. The Reservoir Storage Alternative from 2009 (the year of first shortage occurrence) through the interim period shows average shortage volume between 600 and 750 kafy since shortages are applied both more often and at higher magnitudes. The Conservation Before Shortage Alternative shows average shortage volumes between 400 and about 530 kafy over the interim period with shortages first appearing in 2010. These average shortage volumes are lower than the average values under the No Action Alternative since the shortages under this alternative, although similar in magnitude, are applied less often than those under the No Action Alternative. The same factors underlie the average shortage volumes between 400 and 480 kafy associated with the Basin States Alternative and the Preferred Alternative. Shortages under these two alternatives also first appear in 2010.

The Conservation Before Shortage Alternative shows higher average shortage volumes in the latter years of the interim period when compared to the Basin States Alternative and the Preferred Alternative. This is due to involuntary shortages of higher magnitudes occurring at higher frequencies in the latter years under the Conservation Before Shortage Alternative to keep Lake Mead above elevation 1,000 feet msl. Conversely, the Basin States Alternative and the Preferred Alternative assume that when Lake Mead is at or below elevation 1,025 feet msl, additional consultations will occur in order to determine what further actions might be necessary. For modeling purposes, it was assumed that shortages with a magnitude of 600 kaf would continue for Lake Mead elevations below 1,025 feet msl for the Basin States Alternative and the Preferred Alternative.

An alternate way to analyze the probability and magnitude of shortages between alternatives is to compare the cumulative distribution of shortages over a period of time. Figure 4.4-4 presents the cumulative distribution of both voluntary and involuntary shortages for the interim period, 2008 through 2026.

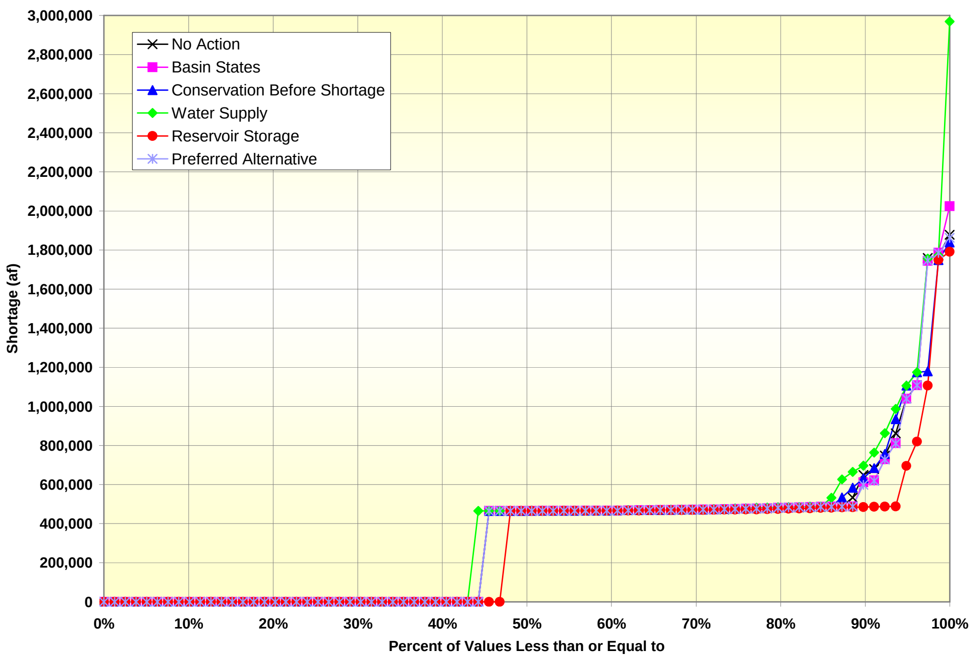
Figure 4.4-4
Involuntary and Voluntary Lower Basin Shortages
Comparison of Action Alternatives to No Action Alternative
Years 2006 through 2026



Under the No Action Alternative, shortages between 490 and 560 kafy would be applied about 35 percent of the time, with shortages of greater magnitudes occurring about three percent of the time over the interim period. Under the Basin States and Conservation Before Shortage Alternatives, and the Preferred Alternative, shortages occur less often than under the No Action Alternative (about 26, 24, and 21 percent of the time, respectively), with the slightly lower probability of the Preferred Alternative due to the assumption of larger volumes of conserved water being stored in Lake Mead. The Reservoir Storage Alternative shows that shortages of magnitudes greater than 600 kafy would occur about 12 percent of the time.

Figure 4.4-5 provides the cumulative distribution of shortages for the period between 2027 through 2060. Although all alternatives were assumed to revert back to the modeled operational criteria used under the No Action Alternative in 2027, the differences in the cumulative distribution are attributed to differences in Lake Powell and Lake Mead elevations between the alternatives at the end of the interim period (2026). For example, the occurrence of large shortages (up to 2.97 maf) at low probabilities under the Water Supply Alternative is due to large shortages that must be applied in order to return Lake Mead to above elevation 1,000 feet msl for some traces in 2027 and 2028.

Figure 4.4-5
Involuntary and Voluntary Lower Basin Shortages
Comparison of Action Alternatives to No Action Alternative
Years 2027 through 2060



Tables 4.4-5 through 4.4-9 present the probability of occurrence of shortages of various magnitudes for years 2017, 2026, 2027, 2040, and 2060 for each alternative. Also shown are the probabilities of involuntary shortages only and the probabilities of both voluntary and involuntary shortages for the Conservation Before Shortage Alternative.

Table 4.4-5
Distribution of Shortages, Year 2017 (percent)

Shortage (kaf)	No Action	Basin States	Conservation Before Shortage		Water Supply	Reservoir Storage	Preferred Alternative
			Involuntary	Voluntary & Involuntary Shortage			
< 400	0	0	0	0	2	0	0
400 - 499	45	15	0	14	0	0	16
500 - 599	0	13	0	11	0	0	8
600 - 799	0	3	0	1	0	18	3
800 - 999	0	0	1	1	0	16	0
1,000 – 1,199	1	0	0	0	0	2	0
1,200 – 1,399	0	0	0	0	0	0	0
1,400 – 1,599	0	0	0	0	0	0	0
1,600 – 1,799	0	0	0	0	0	0	0
1,800 – 1,999	0	0	0	0	0	0	0
2,000 – 2,499	0	0	0	0	0	0	0
> 2,500	0	0	0	0	0	0	0

Table 4.4-6
Distribution of Shortages, Year 2026 (percent)

Shortage (kaf)	No Action	Basin States	Conservation Before Shortage		Water Supply	Reservoir Storage	Preferred Alternative
			Involuntary	Voluntary & Involuntary Shortage			
< 400	0	0	0	0	12	0	0
400 – 499	34	15	1	19	0	0	24
500 – 599	0	13	0	10	0	0	11
600 – 799	7	7	3	4	0	18	6
800 – 999	6	0	2	2	0	14	0
1,000 – 1,199	1	0	0	0	0	5	0
1,200 – 1,399	0	0	0	0	0	0	0
1,400 – 1,599	0	0	0	0	0	0	0
1,600 – 1,799	0	0	0	0	0	0	0
1,800 – 1,999	1	0	1	1	0	0	0
2,000 – 2,499	0	0	0	0	0	0	0
> 2,500	0	0	0	0	0	0	0

Table 4.4-7
Distribution of Shortages, Year 2027 (percent)

Shortage (kaf)	No Action	Basin States	Conservation Before Shortage: Involuntary	Conservation Before Shortage: Voluntary & Involuntary Shortage	Water Supply	Reservoir Storage	Preferred Alternative
< 400	0	0	0	0	0	0	0
400 – 499	38	48	44	44	37	38	50
500 – 599	1	0	0	0	1	0	0
600 – 799	3	2	2	2	3	0	0
800 – 999	2	0	2	2	2	0	1
1,000 – 1,199	1	0	1	1	0	0	0
1,200 – 1,399	0	0	0	0	0	0	0
1,400 – 1,599	0	0	0	0	0	0	0
1,600 – 1,799	3	0	0	0	0	0	0
1,800 – 1,999	1	0	1	1	1	0	0
2,000 – 2,499	0	1	0	0	3	0	0
> 2,500	0	0	0	0	4	0	0

Table 4.4-8
Distribution of Shortages, Year 2040 (percent)

Shortage (kaf)	No Action	Basin States	Conservation Before Shortage: Involuntary	Conservation Before Shortage: Voluntary & Involuntary Shortage	Water Supply	Reservoir Storage	Preferred Alternative
< 400	0	0	0	0	0	0	0
400 – 499	37	35	33	33	34	44	36
500 – 599	2	0	2	2	1	0	0
600 – 799	4	5	3	3	5	0	4
800 – 999	2	2	2	2	3	2	1
1,000 – 1,199	2	3	7	7	3	1	4
1,200 – 1,399	0	0	0	0	0	0	0
1,400 – 1,599	0	0	0	0	0	0	0
1,600 – 1,799	3	3	2	2	3	2	3
1,800 – 1,999	0	1	0	0	1	0	1
2,000 – 2,499	0	0	0	0	0	0	0
> 2,500	0	0	0	0	0	0	0

Table 4.4-9
Distribution of Shortages, Year 2060 (percent)

Shortage (kaf)	No Action	Basin States	Conservation Before Shortage: Involuntary	Conservation Before Shortage: Voluntary & Involuntary Shortage	Water Supply	Reservoir Storage	Preferred Alternative
< 400	0	0	0	0	0	0	0
400 – 499	54	52	50	50	51	53	52
500 – 599	1	1	3	3	2	1	1
600 – 799	4	6	6	6	4	4	6
800 – 999	3	1	1	1	2	1	1
1,000 – 1,199	3	3	4	4	3	4	3
1,200 – 1,399	0	0	0	0	0	0	0
1,400 – 1,599	0	0	0	0	0	0	0
1,600 – 1,799	3	3	3	3	3	3	3
1,800 – 1,999	1	1	0	0	1	0	1
2,000 – 2,499	0	0	0	0	0	0	0
> 2,500	0	0	0	0	0	0	0

The maximum amount of shortage for each alternative for each year is presented in Figure 4.4-6. Table 4.4-10 lists the maximum values for specific years. The large shortages in 2027 and 2028 shown for the Water Supply Alternative (Figure 4.4-6) are due to shortages that must be applied in order to return Lake Mead to above elevation 1,000 feet msl after the interim period. By contrast, the Reservoir Storage Alternative has the lowest maximum shortage of any of the alternatives in 2027 because the reservoirs would be maintained at relatively higher elevations. By 2040, all alternatives have converged essentially to the No Action Alternative values.

Sensitivity of Shortage Conditions to Storage and Delivery Mechanism. The mechanism to store and deliver conserved system and non-system water assumed as part of the Basin States, Conservation Before Shortage, and Reservoir Storage Alternatives, and the Preferred Alternative, could potentially affect the probability of shortages. Because a potential effect of the storage and delivery mechanism is an increase in the volume of water in Lake Mead, a Shortage Condition is likely to occur less often with the storage and delivery mechanism in place.

Figure 4.4-6
Involuntary and Voluntary Lower Basin Shortages
Comparison of Action Alternatives to No Action Alternative
Maximum Shortage Volumes

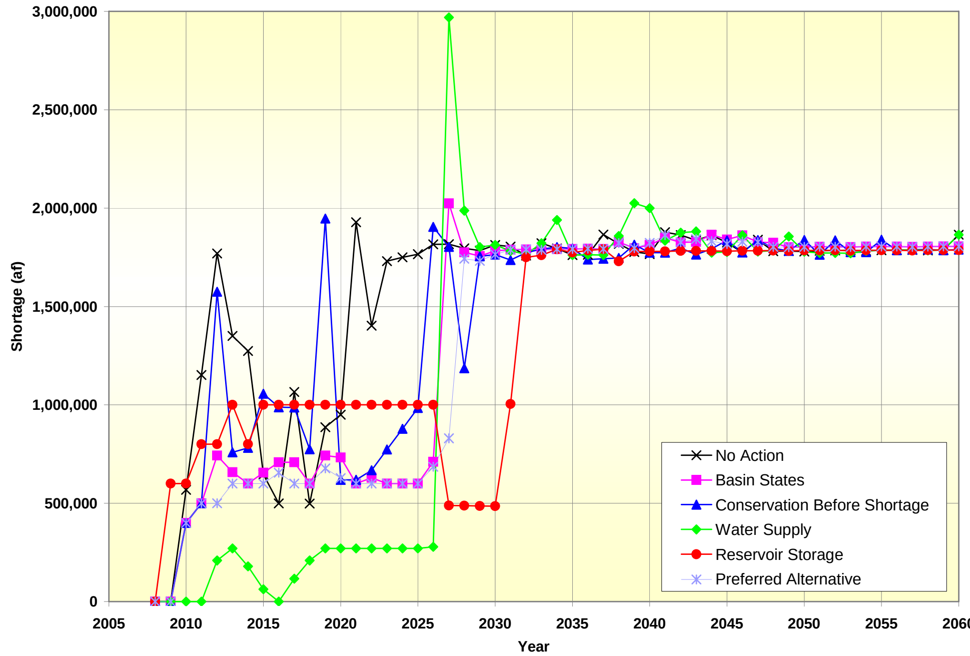


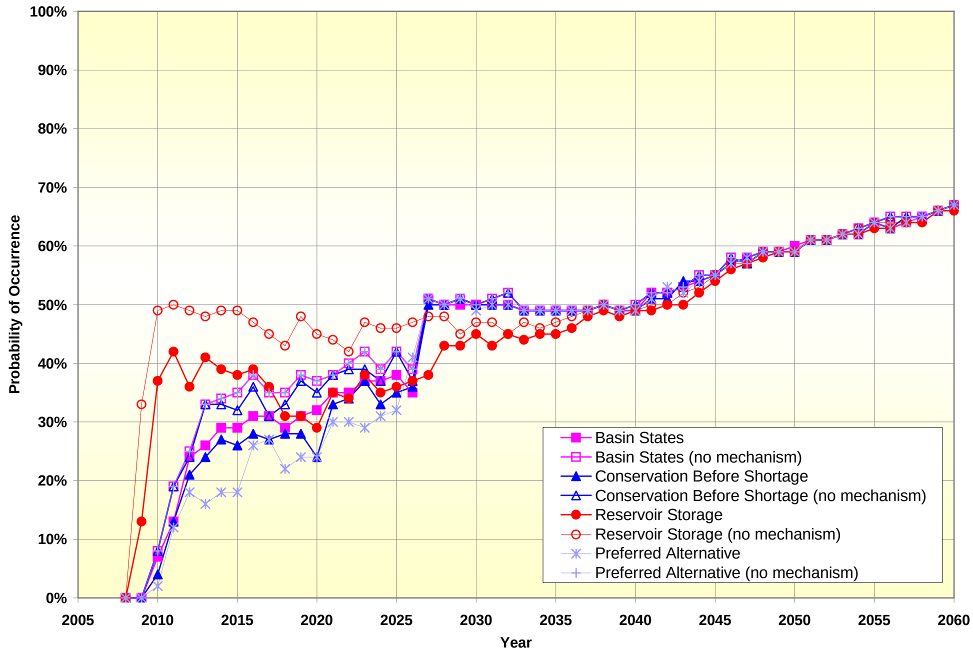
Table 4.4-10
Maximum Volume of Involuntary and Voluntary Shortage to the Lower Basin for Specific Years (af)
Comparison of Action Alternatives to No Action Alternative

Year	No Action	Basin States	Conservation Before Shortage	Water Supply	Reservoir Storage	Preferred Alternative
2008	0	0	0	0	0	0
2017	1,065,961	707,930	987,421	116,530	1,000,000	600,000
2026	1,816,439	711,370	1,904,067	279,000	1,000,000	685,470
2027	1,817,357	2,024,093	1,803,329	2,969,371	488,644	829,717
2040	1,766,650	1,812,428	1,774,108	1,999,447	1,779,919	1,823,325
2060	1,864,875	1,805,591	1,788,498	1,864,875	1,787,346	1,805,591

An analysis of the sensitivity of the occurrence of a Shortage Condition to the storage and delivery mechanism was performed by comparing these four alternatives with and without the mechanism in place. Without the mechanism in place, it was assumed that the voluntary shortages (i.e., reduced water deliveries due to conservation proposed to occur at Lake Mead elevations at and below 1,075 feet msl) proposed in the Conservation Before Shortage Alternative would occur. Under this assumption, the conserved water would remain in Lake Mead. All other conservation activities assumed to be associated with the storage and delivery mechanism as described in Appendix M were assumed not to exist for the Conservation Before Shortage, Basin States and Reservoir Storage Alternatives, and the Preferred Alternative.

Figure 4.4-7 presents the probability of involuntary and voluntary shortages for each of the four alternatives with and without the mechanism in place. For each alternative, the inclusion of the mechanism has the effect of decreasing the probability of shortages. Under the Basin States and Conservation Before Shortage Alternatives, the probability of shortage is reduced an average of about five percent from 2010 through 2026. Although the Conservation Before Storage Alternative assumes a greater participation in the storage and delivery mechanism relative to the Basin States Alternative, these results are similar due to the assumption that voluntary conservation would occur under the Conservation Before Storage Alternative even without the mechanism in place. Under the Reservoir Storage Alternative and the Preferred Alternative, the reduction in the probability of shortage is greater, an average of approximately ten percent from 2010 through 2026. Without the storage and delivery mechanism, the probabilities under the Preferred Alternative and the Basin States Alternative are identical because the other modeled operational assumptions are identical.

Figure 4.4-7
Involuntary and Voluntary Lower Basin Shortages
Comparison of Action Alternatives With and Without a Storage and Delivery Mechanism
Probability of Occurrence of Any Shortage Volume



Probability of Multi-year Shortages. It is possible that under some hydrologic conditions, water supply in the Colorado River system may be insufficient to satisfy 7.5 maf of consumptive use in the Lower Division states in two or more consecutive years. In this and subsequent sections, these occurrences of shortages in consecutive years are termed "multi-year shortages". In this section, an analysis of the probability of multi-year shortages is presented. Two factors were considered in this analysis: 1) the frequency of occurrence of multi-year shortages of specific durations; and 2) the magnitude of the shortages observed in those consecutive years.

Multi-year shortages with volumes per year greater than or equal to 400 kafy, 500 kafy, and 600 kafy with durations of two or more years, five or more years, ten or more years, and fifteen or more years were analyzed. No multi-year shortages with volumes per year equal to or greater than 1.0 mafy were observed to occur under any of the alternatives. The results of analyses of multi-year shortages with annual shortage volumes greater than or equal to 400 kafy of durations of two or more years, five or more years, ten or more years and 15 or more years, are shown in Figures 4.4-8 through 4.4-11. The figures and tables that present the results of the analyses of multi-year shortages with annual shortage volumes greater than or equal to 500 kafy and 600 kafy are provided in Appendix P.

Figure 4.4-8
Consecutive Shortages of Two Years or Greater
Comparison of Action Alternatives to No Action Alternative
Probability of Shortage per Year Greater Than or Equal to 400 kaf

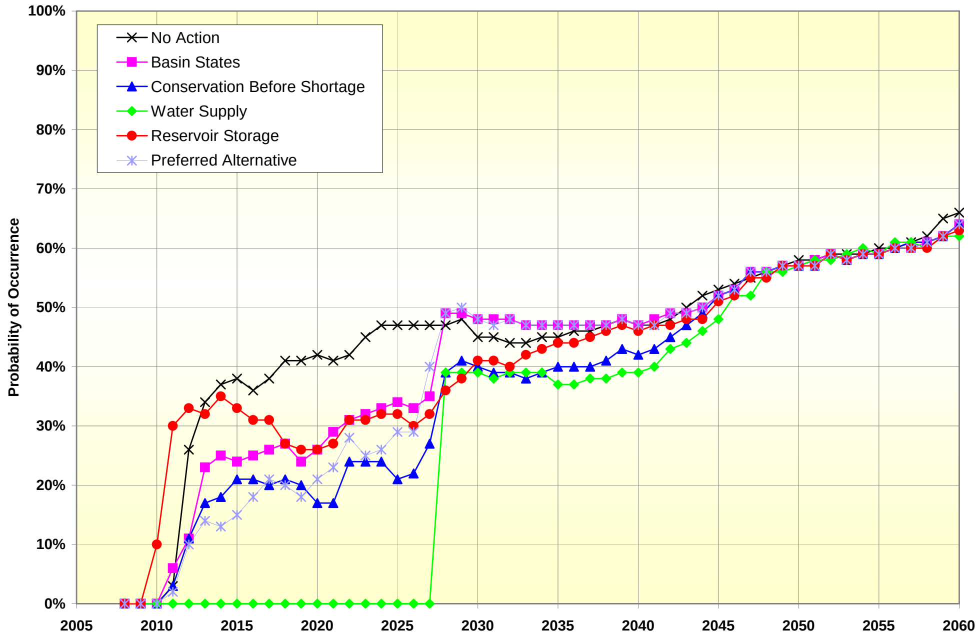


Figure 4.4-9
Consecutive Shortages of Five Years or Greater
Comparison of Action Alternatives to No Action Alternative
Probability of Shortage per Year Greater Than or Equal to 400 kaf

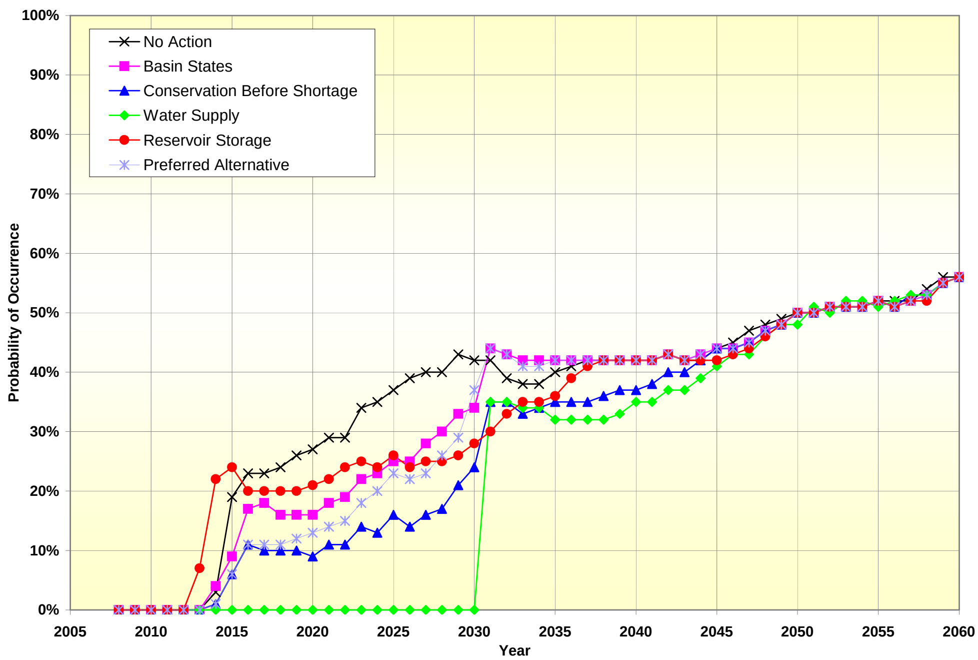


Figure 4.4-10
Consecutive Shortages of Ten Years or Greater
Comparison of Action Alternatives to No Action Alternative
Probability of Shortage per Year Greater Than or Equal to 400 kaf

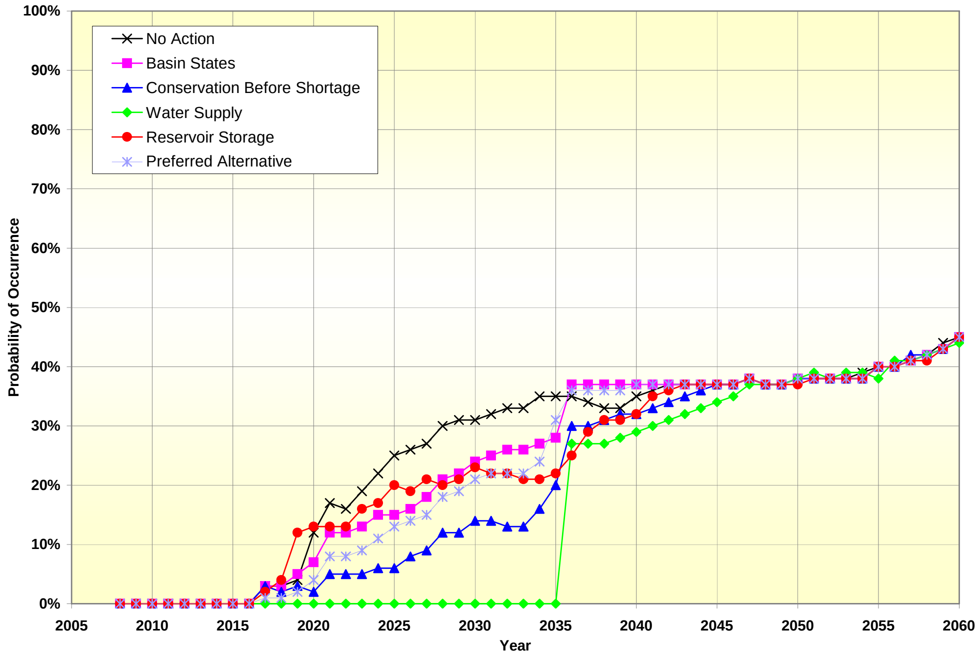
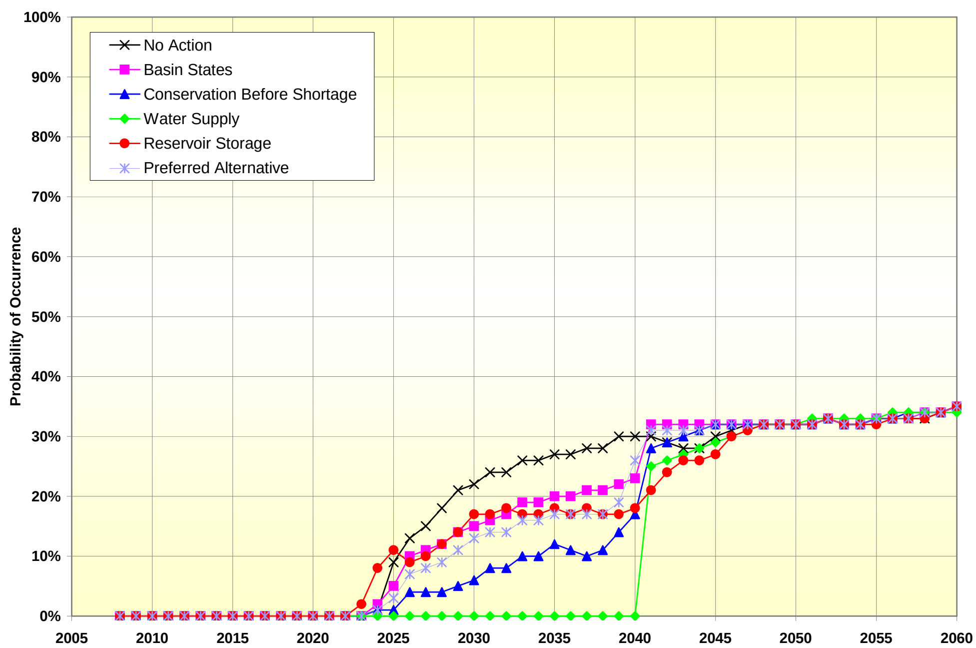


Figure 4.4-11
Consecutive Shortages of 15 Years or Greater
Comparison of Action Alternatives to No Action Alternative
Probability of Shortage per Year Greater Than or Equal to 400 kaf



As shown in Figures 4.4-8 through 4.4-11, the probability of multi-year shortages for volumes greater than or equal to 400 kafy decreases as the duration of the multi-year shortage increases for all alternatives. For all durations (greater than or equal to two, five, ten and 15 years), the No Action Alternative has the highest probability of multi-year shortages and the Water Supply Alternative has the lowest probability (zero) during the interim period. The Conservation Before Shortage Alternative and the Preferred Alternative have lower probabilities of multi-year shortages of greater than 400 kafy for all durations than the Basin States Alternative, due primarily to the assumption of increased participation in the storage and delivery mechanism.

Table 4.4-11 presents the probabilities of occurrence depicted in Figures 4-4.8 through 4.4-11 for various durations of selected years during the interim period. The Preferred Alternative and the Conservation Before Shortage Alternative show an approximately 11 percent probability of a multi-year shortage with annual shortage volumes greater than or equal to 400 kaf lasting for five or more years by the year 2016 as compared to 17 percent, 20 percent, and 23 percent for the Basin States and Reservoir Storage Alternatives, and the No Action Alternative, respectively.

The results of the analyses of multi-year shortages with annual shortage volumes greater than or equal to 500 kafy are presented in Table P-WD2 and Figures P-WD-5 through P-WD-8 in Appendix P; a summary is presented here. Multi-year shortages with annual shortage volumes equal to or greater than 500 kaf are most likely to occur under the Reservoir Storage Alternative with probabilities of approximately 35 percent for durations of two or more years and 26 percent for durations of five or more years. Multi-year shortages with annual shortage volumes greater than 500 kaf also occur under the No Action Alternative at durations of two and five or more years, but only in the years up to about 2015 due to the assumptions regarding shortages under the No Action Alternative and the assumed decreasing 4th priority schedules (Appendix D). These assumptions result in shortages of less than 500 kafy in years after 2015. Multi-year shortages of 500 kafy or greater also occur under the Basin States, Conservation Before Shortage, and Water Supply alternatives, with relatively low probabilities of one to four percent over the interim period. Multi-year shortages of 500 kafy or greater were not observed under the Preferred Alternative.

The results of the analyses of multi-year shortages with annual shortage volumes greater than or equal to 600 kafy are shown in Table P-WD-3 and Figures P-WD-9 through P-WD-12 in Appendix P; a summary is presented here. Multi-year shortages with annual shortage volumes equal to or greater than 600 kafy are likely to occur only under the Reservoir Storage Alternative. The probabilities of shortages occurring in two or more consecutive years are identical to the probabilities seen at the 400 and 500 kaf level because 600 kaf is the lowest shortage level in the Reservoir Storage Alternative. For the No Action Alternative, and the Conservation Before Shortage and Water Supply alternatives, multi-year shortages with annual shortage volumes greater than 600 kaf are only observed for durations of two or more years and with very small probabilities (one to three percent in just a few years during the interim period). Multi-year shortages of 600 kafy or greater were not observed under the Basin States Alternative and the Preferred Alternative.

Table 4.4-11
Multi-year Shortages with Durations of Two or More Years, Five or More Years, Ten or More Years, and 15 or More Years
Comparison of Action Alternatives to No Action Alternative, Probability of Shortage per Year Greater Than or Equal to 400 kaf

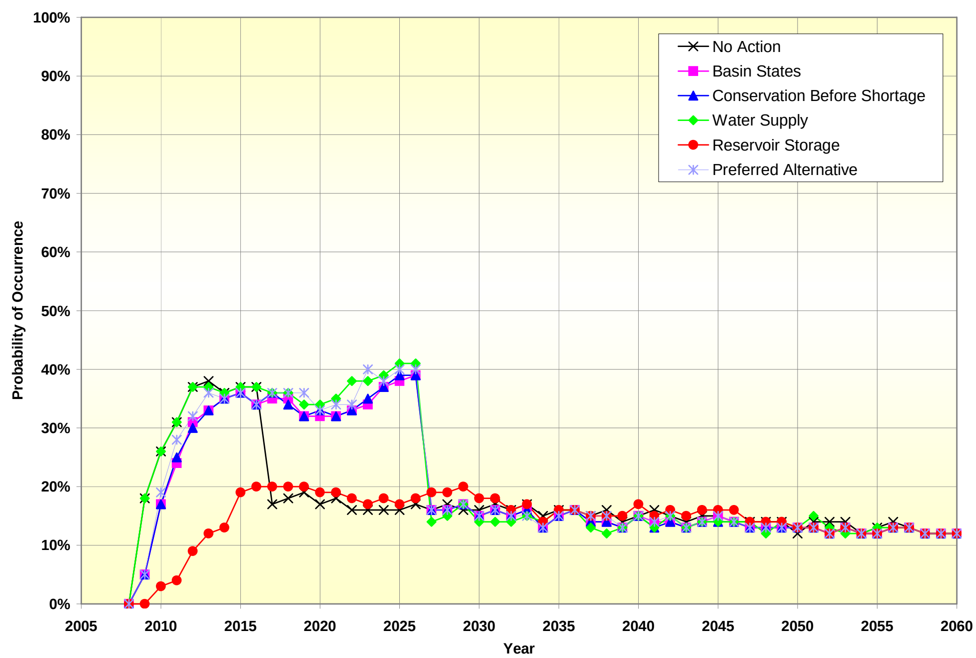
	No Action	Basin States	Conservation Before Shortage	Water Supply	Reservoir Storage	Preferred Alternative
Probability of Annual Shortage Volume Equal to or Greater Than to 400 kaf Occurring in Two or More Consecutive Years (percent)						
2008	0.0	0.0	0.0	0.0	0.0	0.0
2010	0.0	0.0	0.0	0.0	10.0	0.0
2016	36.0	25.0	21.0	0.0	31.0	18.0
2020	42.0	26.0	17.0	0.0	26.0	21.0
2026	47.0	33.0	22.0	0.0	30.0	29.0
2030	45.0	48.0	40.0	39.0	41.0	48.0
2035	45.0	47.0	40.0	37.0	44.0	47.0
2040	47.0	47.0	42.0	39.0	46.0	47.0
2050	58.0	57.0	57.0	57.0	57.0	57.0
2060	66.0	64.0	64.0	62.0	63.0	64.0
Probability of Annual Shortage Volume Equal to or Greater Than 400 kaf Occurring in Five or More Consecutive Years (percent)						
2008	0.0	0.0	0.0	0.0	0.0	0.0
2010	0.0	0.0	0.0	0.0	0.0	0.0
2016	23.0	17.0	11.0	0.0	20.0	11.0
2020	27.0	16.0	9.0	0.0	21.0	13.0
2026	39.0	25.0	14.0	0.0	24.0	22.0
2030	42.0	34.0	24.0	0.0	28.0	37.0
2035	40.0	42.0	35.0	32.0	36.0	42.0
2040	42.0	42.0	37.0	35.0	42.0	42.0
2050	50.0	50.0	50.0	48.0	50.0	50.0
2060	56.0	56.0	56.0	56.0	56.0	56.0
Probability of Annual Shortage Volume Equal to or Greater Than 400 kaf Occurring in Ten or More Consecutive Years (percent)						
2008	0.0	0.0	0.0	0.0	0.0	0.0
2010	0.0	0.0	0.0	0.0	0.0	0.0
2016	0.0	0.0	0.0	0.0	0.0	0.0
2020	12.0	7.0	2.0	0.0	13.0	4.0
2026	26.0	16.0	8.0	0.0	19.0	14.0
2030	31.0	24.0	14.0	0.0	23.0	21.0
2035	35.0	28.0	20.0	0.0	22.0	31.0
2040	35.0	37.0	32.0	29.0	32.0	37.0
2050	38.0	38.0	38.0	38.0	37.0	38.0
2060	45.0	45.0	45.0	44.0	45.0	45.0
Probability of Annual Shortage Volume Equal to or Greater Than 400 kaf Occurring in 15 or More Consecutive Years (percent)						
2008	0.0	0.0	0.0	0.0	0.0	0.0
2010	0.0	0.0	0.0	0.0	0.0	0.0
2016	0.0	0.0	0.0	0.0	0.0	0.0
2020	0.0	0.0	0.0	0.0	0.0	0.0
2026	13.0	10.0	4.0	0.0	9.0	7.0
2030	22.0	15.0	6.0	0.0	17.0	13.0
2035	27.0	20.0	12.0	0.0	18.0	17.0
2040	30.0	23.0	17.0	0.0	18.0	26.0
2050	32.0	32.0	32.0	32.0	32.0	32.0
2060	35.0	35.0	35.0	34.0	35.0	35.0

4.4.4.2 Surplus Conditions

A Surplus Condition exists in a particular year when the Secretary determines that there is sufficient mainstream water available to satisfy in excess of 7.5 maf of consumptive use in the Lower Division states. The elements of the proposed federal action include a modification and/or extension of the ISG and each alternative expresses a particular assumption for determining Surplus conditions (Chapter 2).

Probability of Surplus of Any Amount. Figure 4.4-12 compares the probabilities of a Surplus Condition between the alternatives. For the No Action Alternative, the probability of surplus drops from 37 percent to 17 percent in 2017 due to the expiration of the ISG. For the Basin States, Conservation Before Shortage, and Water Supply alternatives, and the Preferred Alternative, the probabilities of surplus are between 30 percent and 40 percent through 2026 since they assume an extension of some provisions of the ISG. Probabilities for the Basin States and Conservation Before Shortage Alternatives, and the Preferred Alternative are lower compared to the Water Supply Alternative since all three alternatives assume that the ISG would be modified and the more permissive provisions (e.g., Partial Domestic Surplus) would be eliminated. For the Reservoir Storage Alternative, surplus determinations are limited to Quantified Surplus (70R Strategy) and Flood Control Surplus Conditions, beginning in 2008, and that assumption is reflected in the lower probabilities compared to the other action alternatives throughout the interim period. The probabilities for all alternatives converge to around 15 percent after the interim period since they all revert to the modeled operational assumptions used under the No Action Alternative after 2026.

Figure 4.4-12
Surplus Conditions
Comparison of Action Alternatives to No Action Alternative
Probability of Occurrence



Probability of Various Types of Surplus. Figure 4.4-13 presents a comparison of the probability of occurrence of the Partial Domestic Surplus Condition for each alternative. The probability is zero for the Basin States, Conservation Before Shortage, and Reservoir Storage Alternatives, and the Preferred Alternative since no provisions for Partial Domestic Surplus are contained in those alternatives. The probability of Partial Domestic Surplus for the No Action Alternative and the Water Supply Alternative are identical through 2016. After 2016, the probability of Partial Domestic Surplus under the No Action Alternative drops to zero since the ISG expire, while the Water Supply Alternative assumes an extension of the existing ISG through 2026.

Figure 4.4-13
Partial Domestic Surplus Deliveries to Lower Basin States
Comparison of Action Alternatives to No Action Alternative
Probability of Occurrence

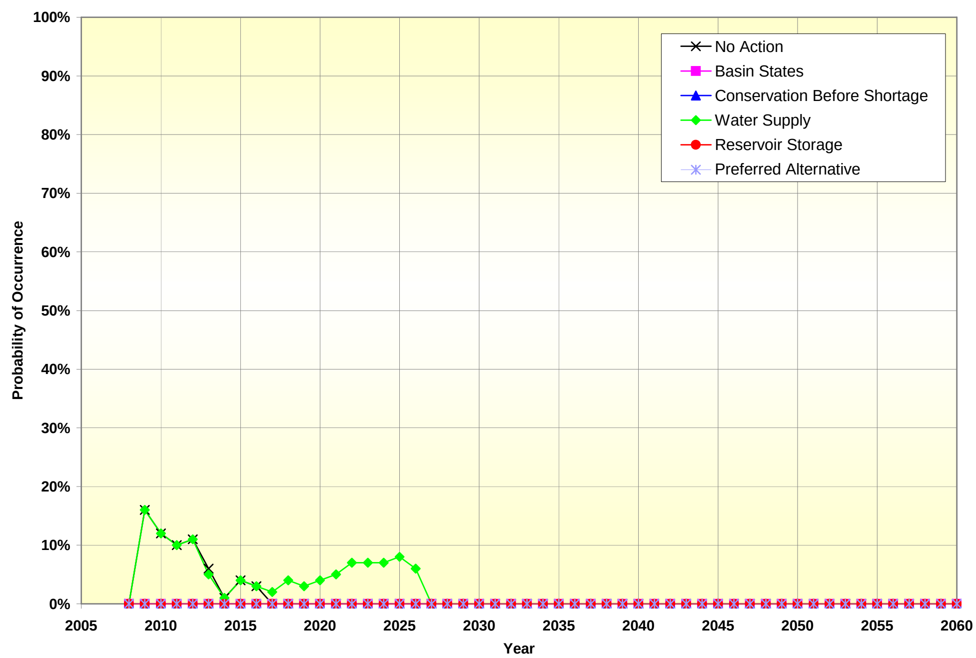


Figure 4.4-14 presents a comparison of the probability of occurrence of the Full Domestic Surplus Condition for each alternative. The probability is zero for the Reservoir Storage Alternative since it does not include a provision for this condition. The probability of Full Domestic Surplus for the No Action Alternative and the Water Supply Alternative are nearly identical through 2016 since they have the same assumptions during that period, with the Water Supply Alternative continuing the Full Domestic Surplus provision through 2026. The Basin States and Conservation Before Shortage Alternatives, and the Preferred Alternative, also have nearly identical probabilities through 2026 since they have the same assumptions during that period. The probabilities for the Basin States and Conservation Before Shortage Alternatives, and the Preferred Alternative are slightly higher than the No Action Alternative and the Water Supply Alternative since they do not have a provision for Partial Domestic Surplus. This keeps the reservoir elevations slightly higher, increasing the chances of a Full Domestic Surplus determination.

Figure 4.4-14
Full Domestic Surplus Deliveries to Lower Basin States
Comparison of Action Alternatives to No Action Alternative
Probability of Occurrence

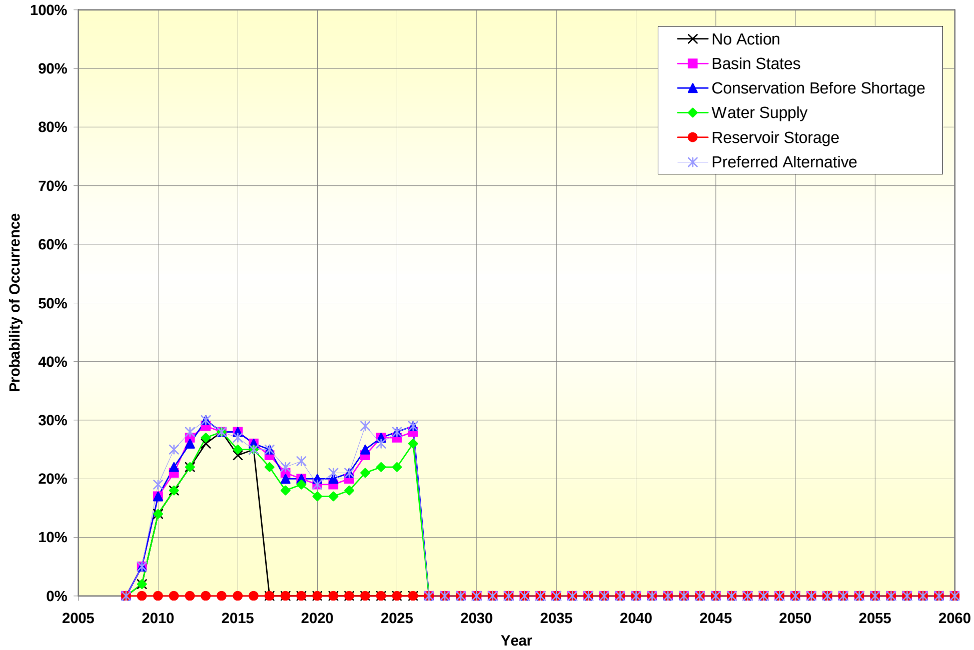


Figure 4.4-15 presents a comparison of the probability of the Quantified (70R) Surplus Condition for each alternative. The probabilities for the No Action Alternative, the Basin States, Conservation Before Shortage, and Water Supply alternatives, and the Preferred Alternative, are nearly identical, with the Reservoir Storage Alternative being slightly higher since it tends to keep the reservoir at higher elevations.

Figure 4.4-15
Quantified Surplus (70R Strategy) Deliveries to Lower Basin States
Comparison of Action Alternatives to No Action Alternative
Probability of Occurrence

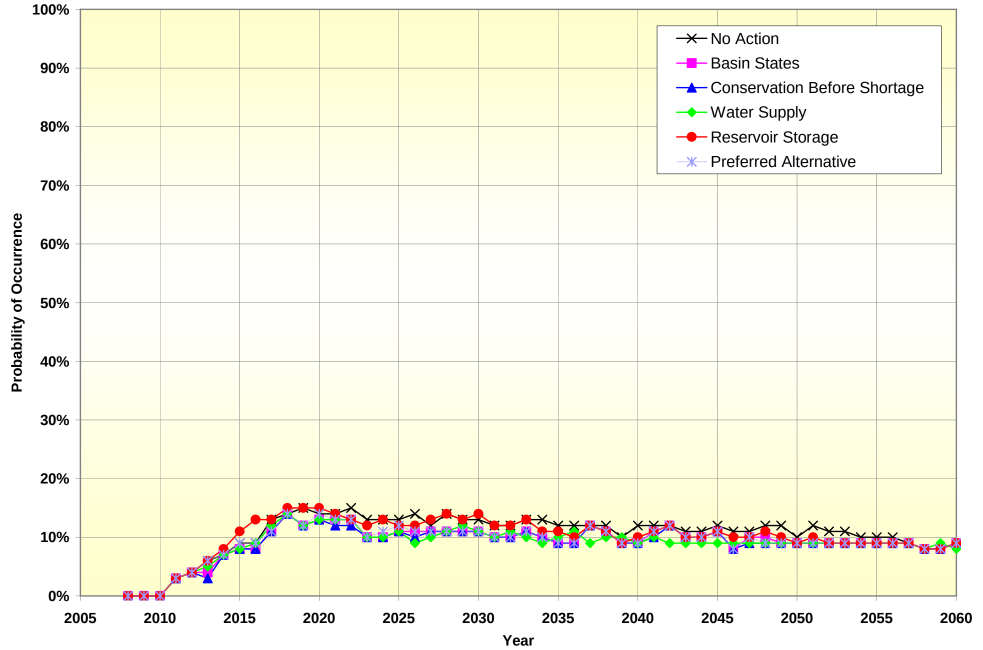
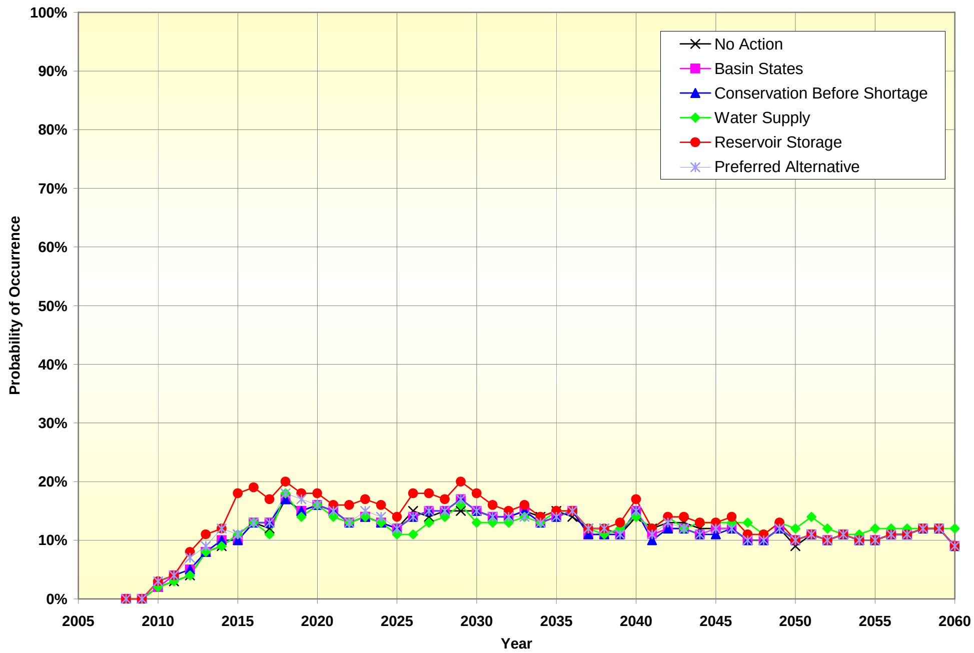


Figure 4.4-16 presents a comparison of the probability of the Flood Control Surplus Condition for each alternative. The probabilities for the No Action Alternative, the Basin States, Conservation Before Shortage, and Water Supply alternatives, and the Preferred Alternative, are nearly identical, with the Reservoir Storage Alternative being slightly higher since it tends to keep the reservoir at higher elevations.

Figure 4.4-16
Flood Control Surplus Deliveries to Lower Basin States
Comparison of Action Alternatives to No Action Alternative
Probability of Occurrence



Sensitivity of Surplus Conditions to Storage and Delivery Mechanism. The mechanism to deliver and store conserved system and non-system water assumed as part of the Basin States, Conservation Before Shortage, and Reservoir Storage Alternatives, and the Preferred Alternative could potentially have an effect on the probability of surplus occurrences. Because a potential outcome of the storage and delivery mechanism is an increase in the volume of water in Lake Mead, a Surplus Condition is likely to occur more often with the storage and delivery mechanism in place.

Figure 4.4-17 presents the sensitivity of the occurrence of a Surplus Condition to the storage and delivery mechanism by comparing these four alternatives with and without the mechanism in place. For each alternative, the inclusion of the mechanism has the effect of slightly increasing the probability of a surplus. An increase of about five percent under the Basin States and Reservoir Storage Alternatives occurs in 2011 and 2015, respectively. The maximum increase under the Conservation Before Shortage Alternative is four percent occurring in 2011. The overall maximum increase in the occurrence of a Surplus Condition is seven percent occurring under the Preferred Alternative in 2011 and 2023.

4.4.4.3 Normal Conditions

The probability of a Normal Condition is shown in Figure 4.4-18. Under the assumption of an initial Lake Mead elevation of 1,114.85 feet msl on January 1, 2008, a Normal Condition would occur for all alternatives with a 100 percent probability in 2008.

Figure 4.4-17
Surplus Deliveries to Lower Basin States
Comparison of Action Alternatives With and Without a Storage and Delivery Mechanism
Probability of Occurrence

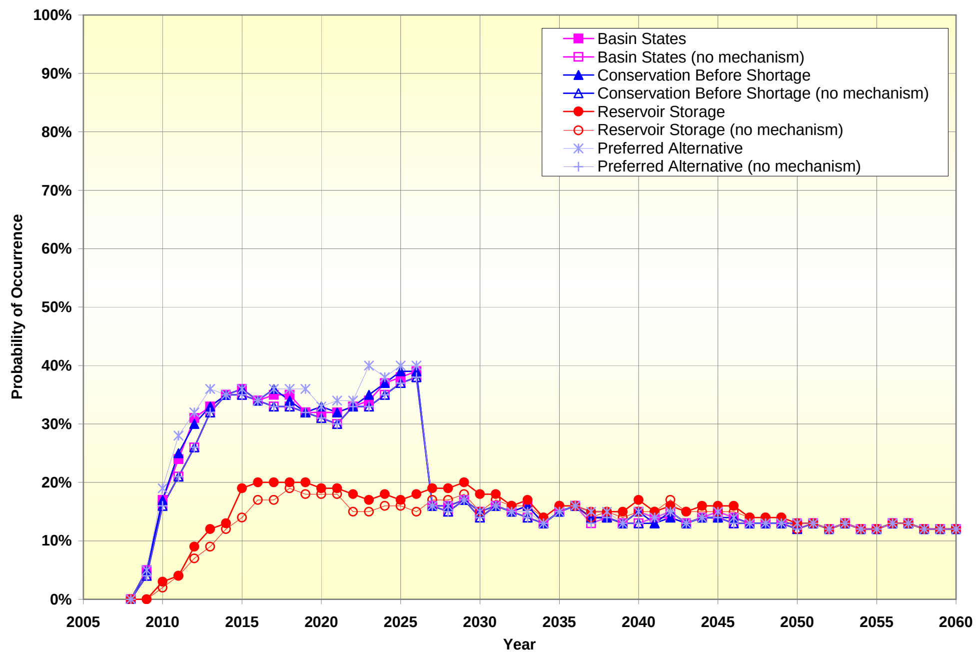
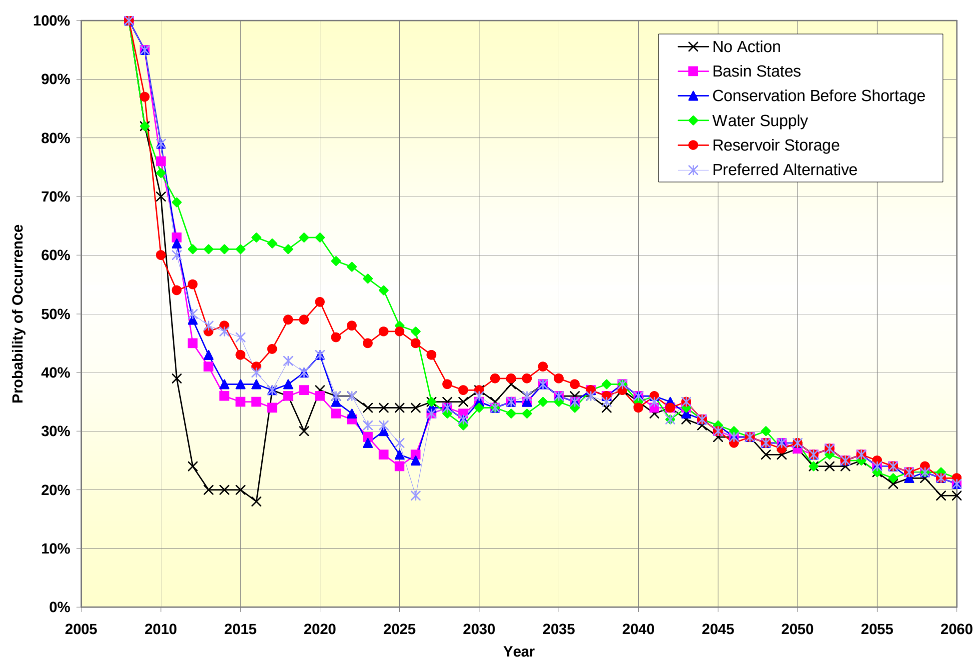


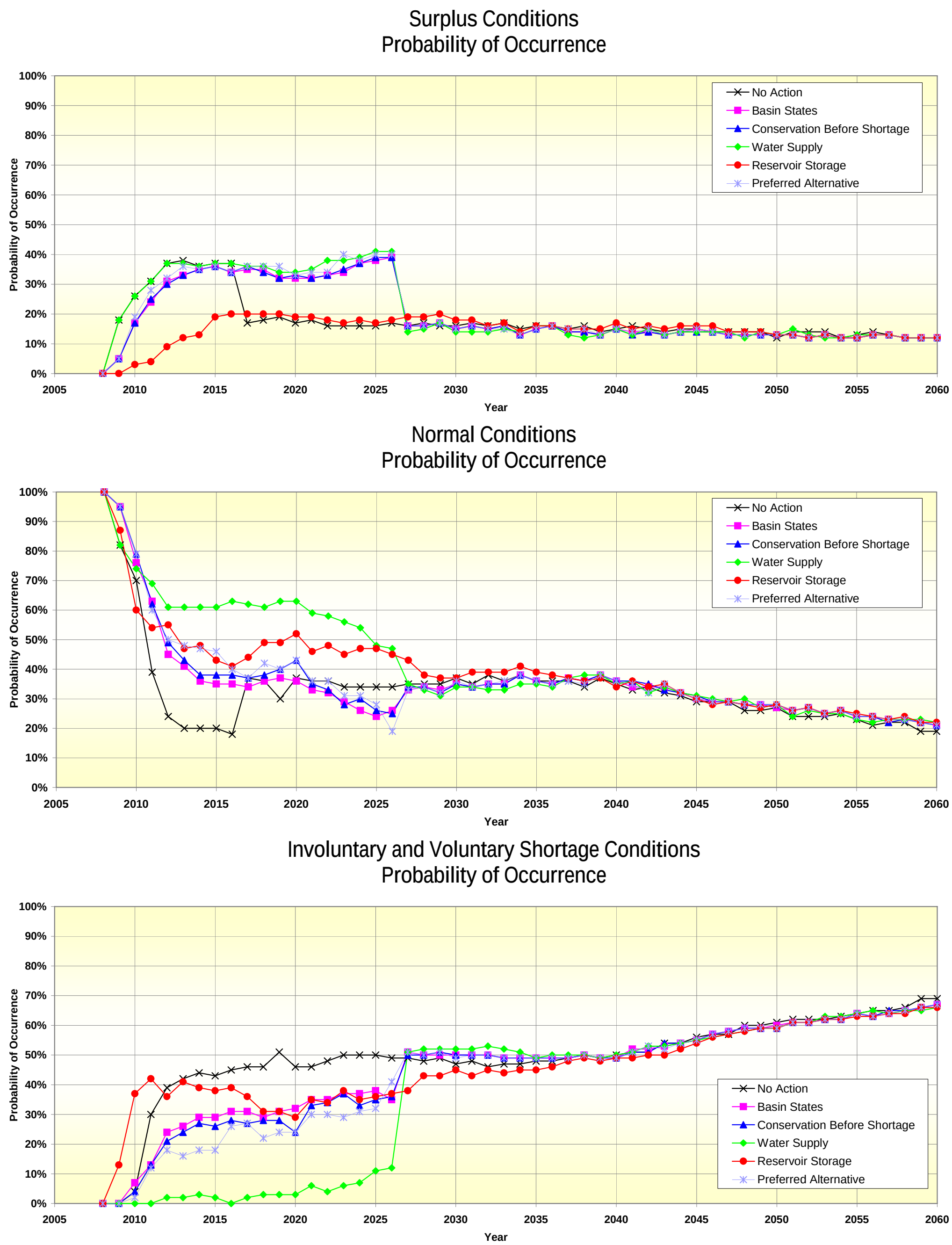
Figure 4.4-18
Normal Conditions
Comparison of Action Alternatives to No Action Alternative
Probability of Occurrence



4.4.4.4 Summary of Water Supply Conditions

Figure 4.4-19 illustrates the probabilities of occurrence for the three water supply conditions (Surplus, Normal, and Shortage) under all alternatives.

Figure 4.4-19
Surplus, Normal, and Shortage (Involuntary and Voluntary) Conditions
Comparison of Action Alternatives to No Action Alternative



4.4.5 Total Water Deliveries to the Lower Division States

This section presents the simulated water deliveries to the three Lower Division states. Deliveries to each state may deviate from a state's normal apportionment due to Surplus or Shortage conditions as well as the storage and delivery of conserved water to and from Lake Mead. For the alternatives that do not include some form of a storage and delivery mechanism (the No Action Alternative and the Water Supply Alternative), water deliveries above or below a state's apportionment occur only during Surplus conditions or Shortage conditions respectively. Water deliveries under the Basin States, Conservation Before Shortage, and Reservoir Storage Alternatives, and the Preferred Alternative in excess of a state's apportionment can occur due to a Surplus Condition as well as when conserved water previously stored in Lake Mead is delivered. Also under these alternatives, water deliveries less than a state's apportionment can occur due to a Shortage Condition as well as when water is being conserved within that state and stored in Lake Mead. In the following sections, the modeled water deliveries are presented with and without the storage and delivery mechanism to facilitate understanding of the differences.

4.4.5.1 Total Water Deliveries to Arizona

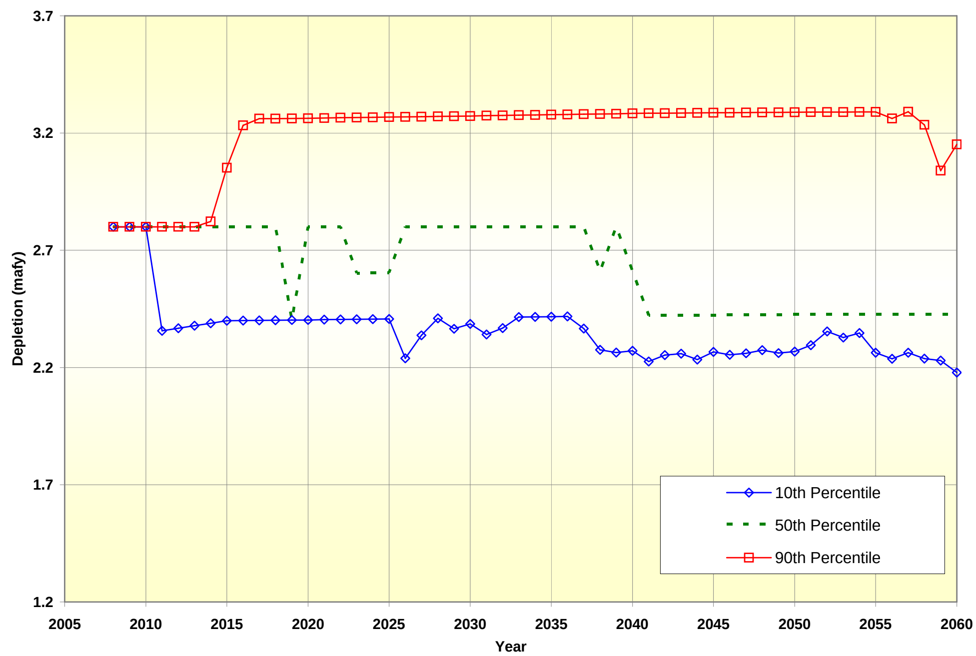
This section presents the simulated water deliveries to Arizona under the No Action Alternative and the action alternatives.

No Action Alternative. Water deliveries to Arizona are projected to fluctuate throughout the 53-year period of analysis reflecting variations in hydrologic conditions. The 90th, 50th, and 10th percentile ranking of modeled water deliveries to Arizona under the No Action Alternative are presented in Figure 4.4-20. Since the No Action Alternative does not include a storage and delivery mechanism, deviations from annual deliveries of 2.8 mafy are due to Shortage and Surplus conditions.

The 90th percentile line generally coincides with Arizona's depletion schedule during full surplus water supply conditions. The exceptions to this are the periods from 2008 through 2015 and 2056 through 2060. As indicated by this 90th percentile line, the probability that the No Action Alternative would provide Arizona's Full Surplus depletion schedule is at least ten percent for the period 2016 through 2055.

The 50th percentile line represents the median annual depletion values. This 50th percentile line generally coincides with Arizona's projected depletion schedule under Normal conditions through year 2018. After 2018, the median annual Arizona modeled depletion values fluctuate between 2.40 maf and 2.80 maf.

Figure 4.4-20
Arizona Modeled Annual Depletions
No Action Alternative
90th, 50th, and 10th Percentile Values



The 10th percentile line represents the depletion values above which 90 percent of the annual depletion values were observed. The 10th percentile annual depletion values were 2.80 maf from 2008 through 2010 and approximately 2.4 maf from 2011 through 2025. Between 2025 and 2037, the 10th percentile annual depletion values fluctuated between 2.24 maf and 2.42 maf, and after 2037, the annual depletion values fluctuated between 2.18 maf and 2.35 maf.

Comparison of Action Alternatives Without the Storage and Delivery Mechanism to No Action Alternative. Figure 4.4-21 provides a comparison of the cumulative distribution of Arizona's depletions under the action alternatives without the storage and delivery mechanism to depletions under the No Action Alternative during the interim period, 2008 through 2026. The results presented in Figure 4.4-21 can be used to compare how often Arizona might expect deliveries above and below its 2.8 mafy apportionment due to surplus and shortage conditions under the different alternatives. The relatively larger shortages occurring at probabilities of about five percent or less under the Conservation Before Shortage Alternative and the No Action Alternative are the result of shortages implemented to keep Lake Mead elevation above 1,000 feet msl.

Figure 4.4-21
Arizona Modeled Annual Depletions
Comparison of Action Alternatives (Without Storage and Delivery Mechanism) to No Action Alternative
Years 2008 through 2026

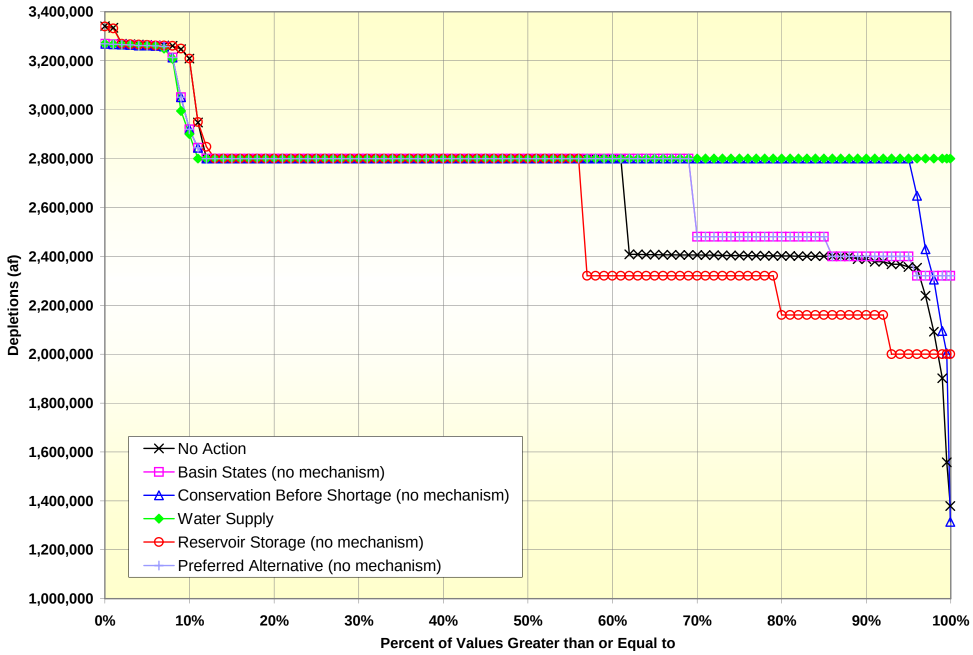


Figure 4.4-22 provides a similar comparison of the cumulative distribution of water deliveries to Arizona under the action alternatives without the storage and delivery mechanism to depletions under the No Action Alternative for the 34-year period 2027 through 2060, that would follow the interim period.

Sensitivity of Total Water Deliveries to Arizona to Storage and Delivery Mechanism. Arizona water deliveries under the Basin States, Conservation Before Shortage, and Reservoir Storage Alternatives, and the Preferred Alternative are impacted by the modeling assumptions made to postulate potential future participation in a storage and delivery mechanism (Appendix M). This section isolates the impacts of those assumptions on Arizona's modeled depletions.

Figure 4.4-22
Arizona Modeled Annual Depletions
Comparison of Action Alternatives (Without Storage and Delivery Mechanism) to No Action Alternative
Years 2027 through 2060

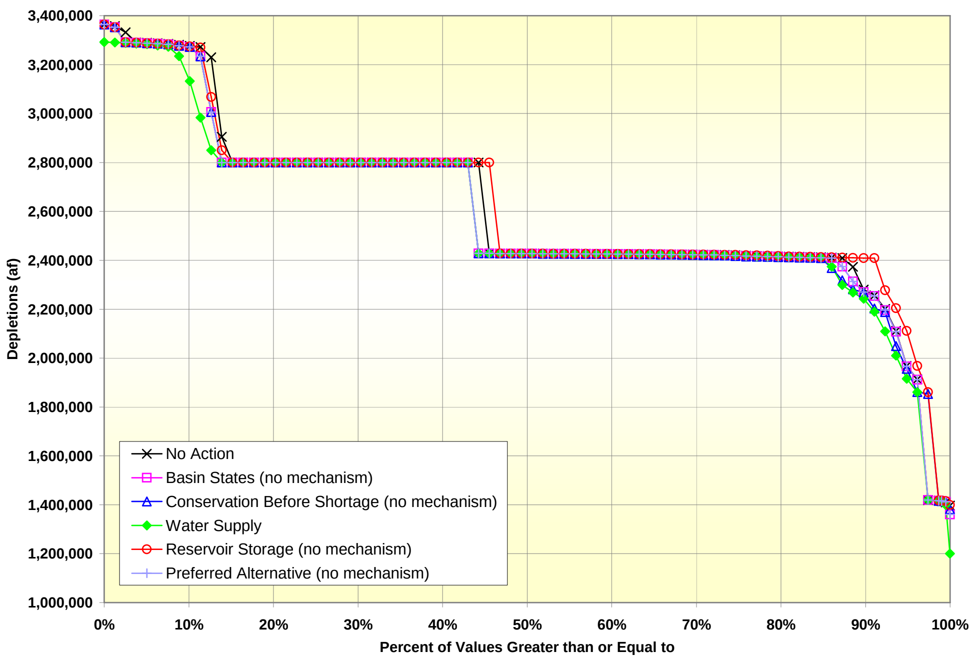


Figure 4.4-23 provides a comparison of the cumulative distribution of Arizona's depletions under the Basin States, Conservation Before Shortage, and Reservoir Storage Alternatives, and the Preferred Alternative, with and without the mechanism in place during the interim period. With the mechanism in place, deliveries of 2.7 mafy are due to the storage of conserved water. With the mechanism removed, occurrences of deliveries less than 2.8 mafy or greater than 2.8 mafy reflect only shortage or surplus conditions respectively. These observations mirror the effects of the mechanism on the probability of voluntary and involuntary total Lower Basin Shortage and Surplus conditions presented in the previous subsection.

Figure 4.4-23
Arizona Modeled Annual Depletions
Comparison of Action Alternatives With and Without Storage and Delivery Mechanism
Years 2008 through 2026

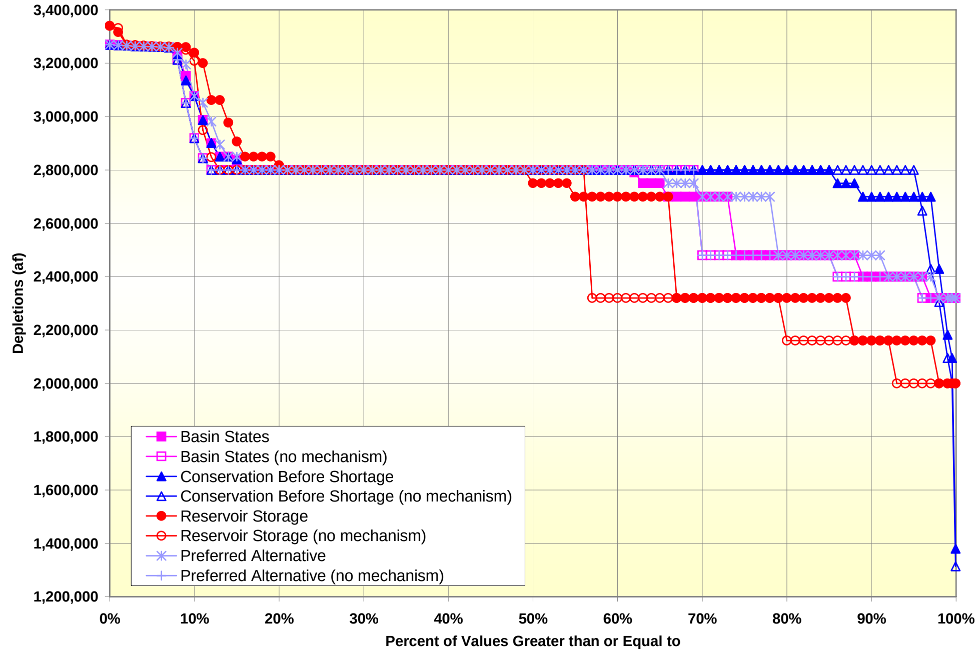
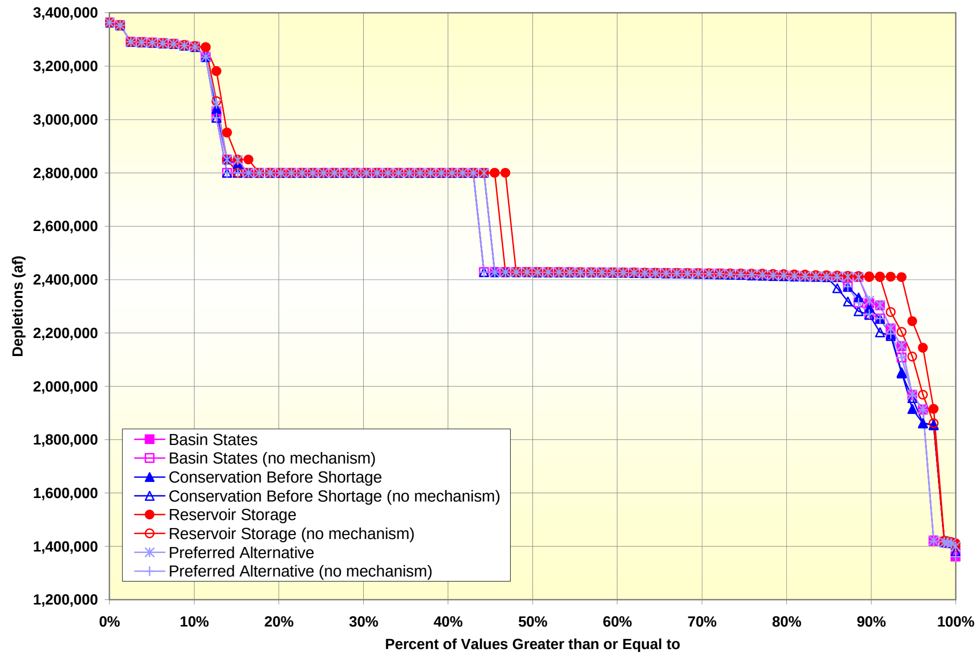


Figure 4.4-24 provides a comparison of the cumulative distribution of Arizona's depletions under the action alternatives that include a storage and delivery mechanism, with and without the mechanism in place for the 34-year period that would follow the interim period. There is almost no effect of the mechanism during these years as it is assumed that only conserved water previously stored in Lake Mead may be delivered during this period.

Figure 4.4-24
Arizona Modeled Annual Depletions
Comparison of Action Alternatives With and Without Storage and Delivery Mechanism
Years 2027 through 2060

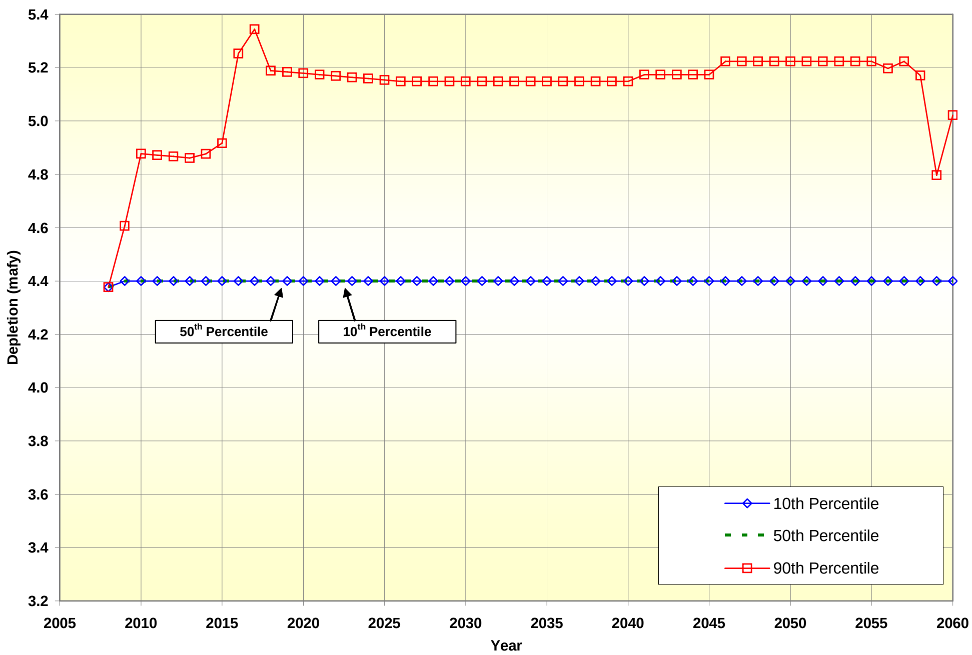


4.4.5.2 Total Water Deliveries to California

This section presents the simulated water deliveries to California under the No Action Alternative and the action alternatives.

No Action Alternative. Water deliveries to California are projected to fluctuate throughout the 53-year period of analysis reflecting variations in hydrologic conditions. The 90th, 50th, and 10th percentile ranking of modeled water deliveries to California under the No Action Alternative are presented in Figure 4.4-25. Since the No Action Alternative does not include a storage and delivery mechanism, deviations from annual deliveries of 4.4 mafy are due to Shortage and Surplus conditions.

Figure 4.4-25
California Modeled Annual Depletions
No Action Alternative
90th, 50th, and 10th Percentile Values



The 90th percentile line generally coincides with California's depletion schedule during full surplus water supply conditions. The exceptions to this are the periods from 2008 through 2015 and from 2056 through 2060. As indicated by this 90th percentile line, the probability that the No Action Alternative would provide California's Full Surplus depletion schedule is at least ten percent for the period from 2016 through 2055.

The 50th percentile line represents the median annual depletion values. This 50th percentile line coincides with California's projected depletion schedule under Normal conditions throughout the 53-year period of analysis.

The 10th percentile line represents the depletion values above which 90 percent of the annual depletion values were observed. The 10th percentile annual depletion values also coincide with California's projected depletion schedule under a Normal Condition throughout the 53-year period of analysis. This means that there is at least a 90 percent probability that California will receive its normal deliveries from 2008 through 2060.

Comparison of Action Alternatives Without the Storage and Delivery Mechanism to No Action Alternative. Figure 4.4-26 provides a comparison of the cumulative distribution of California's depletions under the action alternatives without the storage and delivery mechanism to those of the No Action Alternative during the interim period, 2008 through 2026. The results presented in Figure 4.4-26 can be used to compare how often California might expect deliveries above and below its 4.4 mafy apportionment due to Surplus and Shortage conditions under the different alternatives. Very infrequent (less than one percent of the time) shortages are observed only for the No Action Alternative and the Conservation Before Shortage Alternative due to the assumption that shortages are implemented to keep Lake Mead above elevation 1,000 feet msl. The five percent occurrence of deliveries less than 4.4 mafy when the mechanism is not in place reflects California's scheduled delivery of less than 4.4 maf in 2008 which coincides with scheduled repayment of overruns by IID and CVWD.

Figure 4.4-26
California Modeled Annual Depletions
Comparison of Action Alternatives (Without Storage and Delivery Mechanism) to No Action Alternative
Years 2008 through 2026

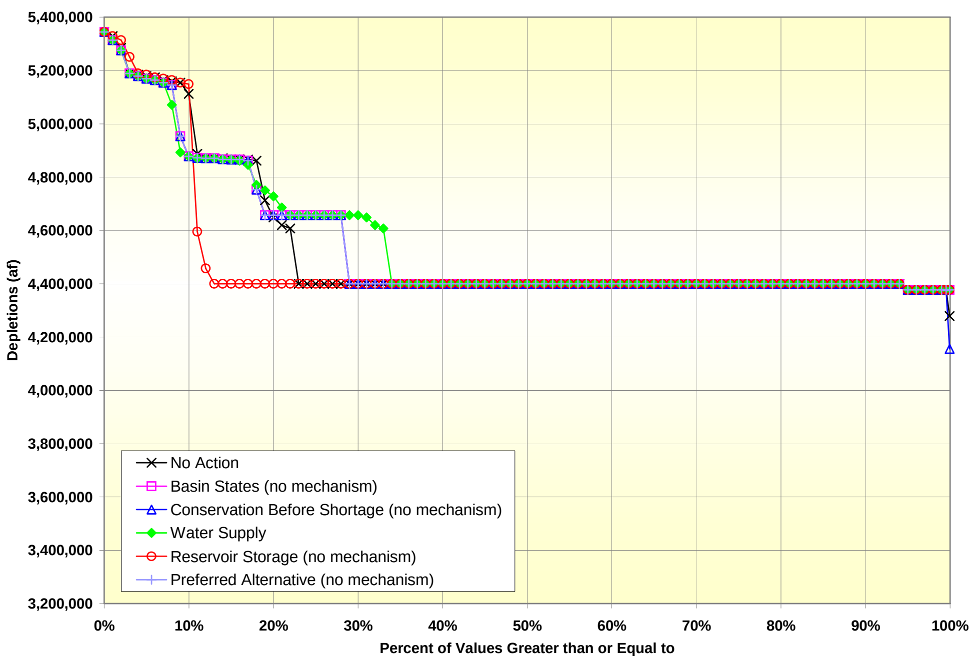
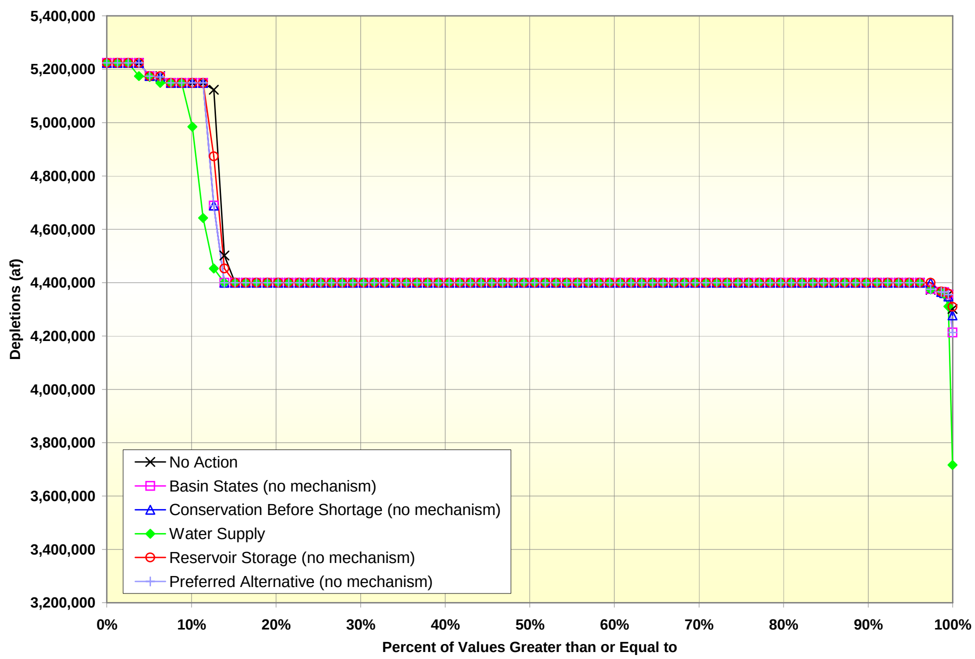


Figure 4.4-27 provides a similar comparison of the cumulative distribution of water deliveries to California under the action alternatives without the storage and delivery mechanism to those of the No Action Alternative for the 34-year period, 2027 through 2060, that would follow the interim period.

Figure 4.4-27
California Modeled Annual Depletions
Comparison of Action Alternatives (Without Storage and Delivery Mechanism) to No Action Alternative
Years 2027 through 2060



Sensitivity of Total Water Deliveries to California to Storage and Delivery Mechanism. California water deliveries under the Basin States, Conservation Before Shortage, and Reservoir Storage Alternatives, and the Preferred Alternative are impacted by modeling assumptions made to postulate potential future participation in a storage and delivery mechanism (Appendix M). This section isolates the impacts of those assumptions on California's depletions.

Figure 4.4-28 provides a comparison of the cumulative distribution of California's depletions under the action alternatives with and without a storage and delivery mechanism in place during the interim period. For alternatives with the mechanism removed, occurrences of deliveries less than 4.4 mafy reflect only Shortage conditions. Removing the mechanism shows that there is almost no occurrence of deliveries less than 4.4 mafy due to shortage conditions. The five percent occurrence of deliveries less than 4.4 mafy when the mechanism is not in place reflects California's scheduled delivery of less than 4.4 maf in 2008 which coincides with scheduled repayment of overruns by IID and CVWD.

Figure 4.4-28
California Modeled Annual Depletions
Comparison of Action Alternatives With and Without Storage and Delivery Mechanism
Years 2008 through 2026

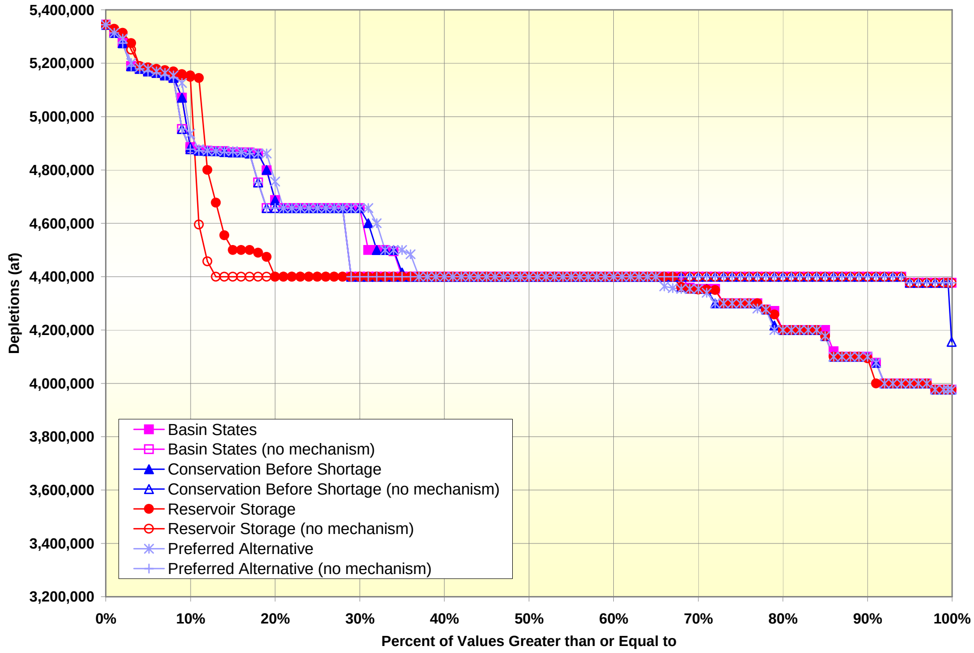
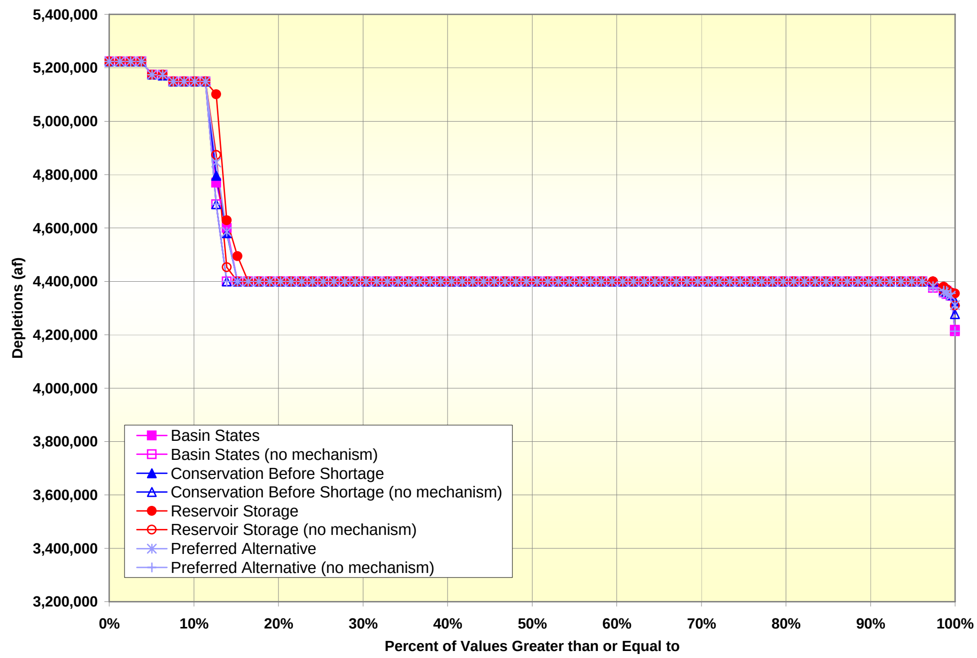


Figure 4.4-29 provides a comparison of the cumulative distribution of California's depletions under the action alternatives that include a storage and delivery mechanism, with and without the mechanism in place for the 34-year period that would follow the interim period. There is almost no effect of the mechanism during these years as it is assumed only conserved water previously stored in Lake Mead may be delivered during this period.

Figure 4.4-29
California Modeled Annual Depletions
Comparison of Action Alternatives With and Without Storage and Delivery Mechanism
Years 2027 through 2060

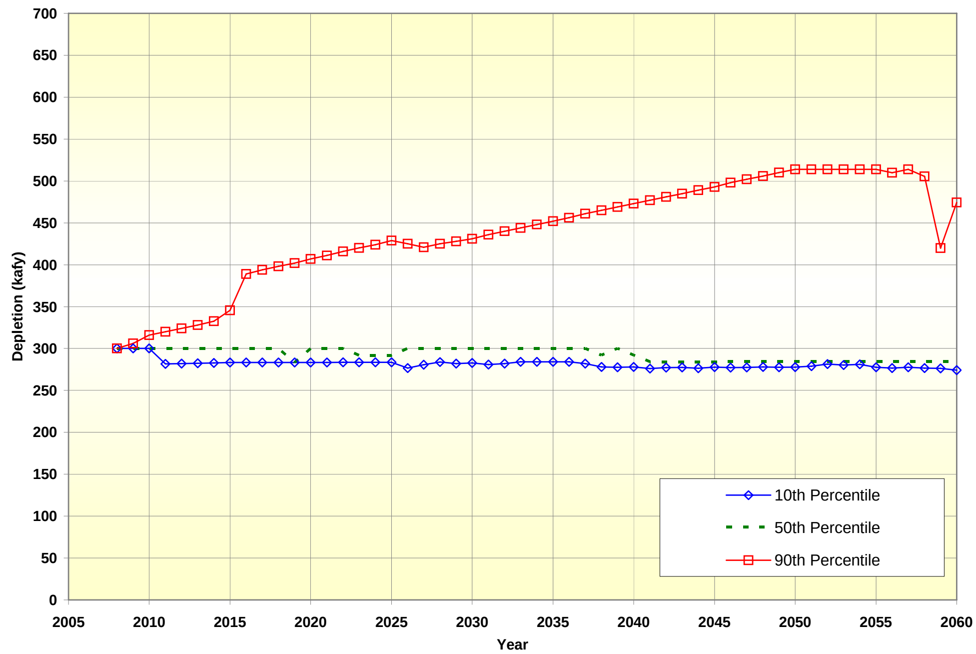


4.4.5.3 Total Water Deliveries to Nevada

This section presents the simulated water deliveries to Nevada under the No Action Alternative and the action alternatives.

No Action Alternative. Water deliveries to Nevada are projected to fluctuate throughout the 53-year period of analysis reflecting variations in hydrologic conditions. The 90th, 50th, and 10th percentile ranking of modeled water deliveries to Nevada under the No Action Alternative are presented in Figure 4.4-30. Since the No Action Alternative does not include a storage and delivery mechanism, deviations from annual deliveries of 300 kafy are due to Shortage and Surplus conditions.

Figure 4.4-30
Nevada Modeled Annual Depletions
No Action Alternative
90th, 50th, and 10th Percentile Values



The 90th percentile line generally coincides with Nevada's depletion schedule during full surplus water supply conditions. The exception to this is the period of 2056 through 2060. As indicated by this 90th percentile line, the probability that the No Action Alternative would provide Nevada's Full Surplus depletion schedule is at least ten percent for the period of 2008 through 2055.

The 50th percentile line represents the median annual depletion values. This 50th percentile line generally coincides with Nevada's projected depletion schedule under a Normal Condition throughout the 53-year period of analysis.

The 10th percentile line represents the depletion values above which 90 percent of the annul depletion values were observed. The 10th percentile annual depletion values were 300 kaf from 2008 to 2010 and fluctuated between 274.1 kaf and 284.1 kaf for the remainder of the 53-year period.

Comparison of Action Alternatives Without the Storage and Delivery Mechanism to No Action Alternative. Figure 4.4-31 provides a comparison of the cumulative distribution of Nevada's depletions under the action alternatives without the storage and delivery mechanism to those of the No Action Alternative during the interim period, 2008 through 2026. The results presented in Figure 4.4-31 can be used to compare how often Nevada might expect deliveries above and below its 300 kafy apportionment due to Surplus and Shortage conditions under the different alternatives. Deliveries of less than 250 kafy observed infrequently under the Basin States and Water Supply alternatives, as well as under the Preferred Alternative, are the result of Lake Mead elevation declining below 1,000 feet msl. Deliveries of less than 250 kafy observed infrequently under the Conservation Before Shortage Alternative, as well as the No Action Alternative, are the result of Lake Mead larger shortages to keep Lake Mead above elevation 1,000 feet msl.

Figure 4.4-31
Nevada Modeled Annual Depletions
Comparison of Action Alternatives (Without Storage and Delivery Mechanism) to No Action Alternative
Years 2008 through 2026

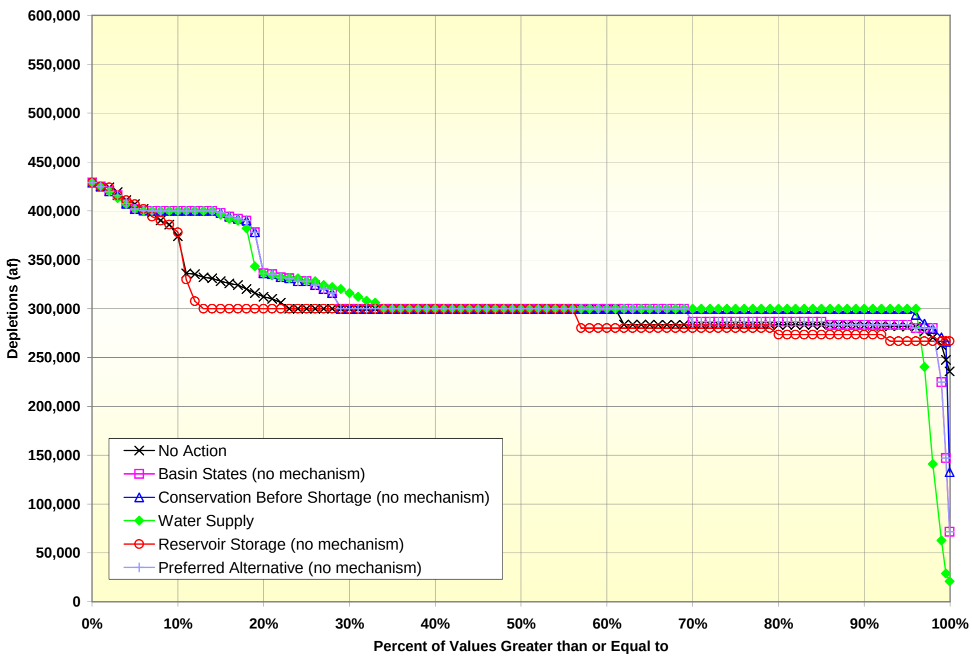
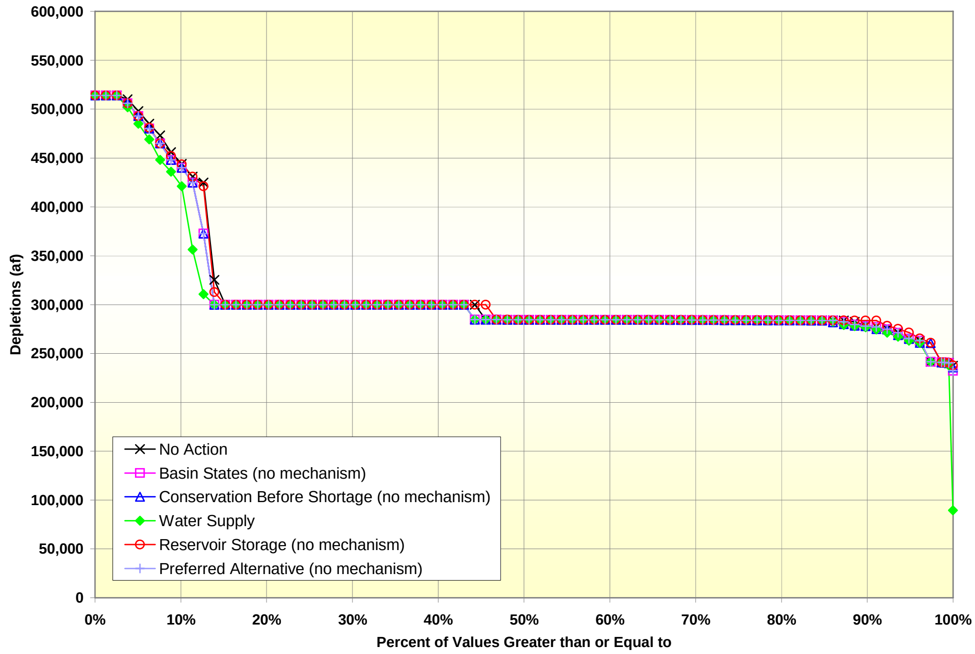


Figure 4.4-32 provides a similar comparison of the cumulative distribution of water deliveries to Nevada under the action alternatives without the storage and delivery mechanism to those of the No Action Alternative for the 34-year period, 2027 through 2060, that would follow the interim period.

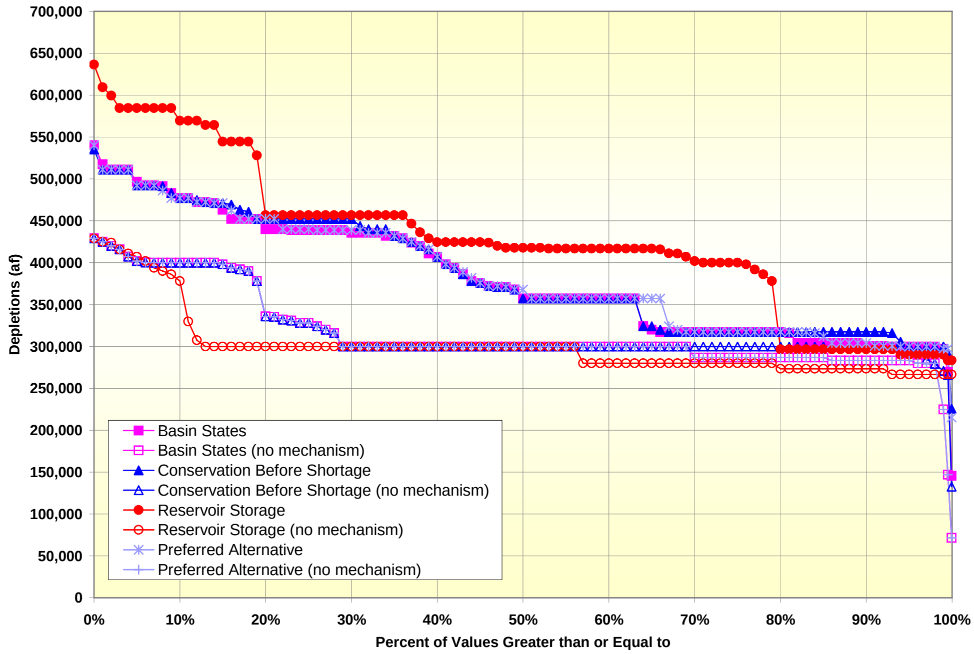
Figure 4.4-32
Nevada Modeled Annual Depletions
Comparison of Action Alternatives (Without Storage and Delivery Mechanism) to No Action Alternative
Years 2027 through 2060



Sensitivity of Total Water Deliveries to Nevada to Storage and Delivery Mechanism. Nevada water deliveries under the Basin States, Conservation Before Shortage, and Reservoir Storage Alternatives, and the Preferred Alternative are impacted by the modeling assumptions made to postulate potential future participation in a storage and delivery mechanism (Appendix M). This section isolates the impacts of those assumptions on Nevada's modeled depletions.

Figure 4.4-33 provides a comparison of the cumulative distribution of Nevada's depletions under the action alternatives with and without a storage and delivery mechanism in place during the interim period. With the mechanism removed the occurrence of deliveries greater than 300 kafy is about 65 percent less under the Reservoir Storage and Conservation Before Shortage Alternatives. Under the Basin States Alternative and the Preferred Alternative, the occurrence of deliveries above 300 kafy is about 55 percent less with the mechanism removed. This indicates that the majority of the occurrences of deliveries above 300 kafy under the Basin States, Conservation Before Shortage, and Reservoir Storage Alternatives, and the Preferred Alternative can be attributed to the delivery of conserved system and non-system water to Nevada. Also, the magnitude of deliveries above 300 kafy is less with the storage and delivery mechanism not in place. Under the Basin States and Conservation Before Shortage Alternatives, and the Preferred Alternative, deliveries range from about 55 kaf to 140 kaf less. Under the Reservoir Storage Alternative, deliveries range from about 100 kaf to 265 kaf less.

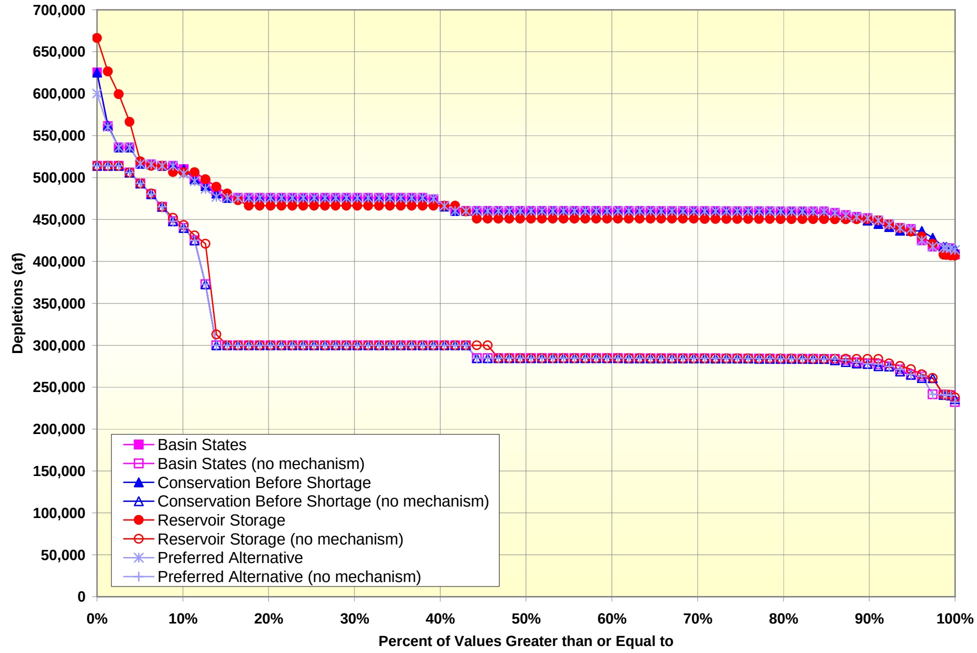
Figure 4.4-33
Nevada Modeled Annual Depletions
Comparison of Action Alternatives With and Without Storage and Delivery Mechanism
Years 2008 through 2026



With the mechanism removed the occurrence of deliveries less than 300 kafy is about 30 percent greater under the Basin States Alternative, two percent greater under the Conservation Before Shortage Alternative, about 40 percent greater under the Reservoir Storage Alternative, and about 30 percent greater under the Preferred Alternative. This indicates that as a result of the delivery of conserved system and non-system water, Nevada does not often receive deliveries less than 300 kafy.

Figure 4.4-34 provides a comparison of the cumulative distribution of Nevada's depletions under the action alternatives that include a storage and delivery mechanism, with and without the mechanism in place for the 34-year period that would follow the interim period. The results of the mechanism removed emphasize the modeling assumption that there is about 170 kafy of conserved system and non-system water available to Nevada after the interim period under these alternatives (Appendix M).

Figure 4.4-34
Nevada Modeled Annual Depletions
Comparison of Action Alternatives With and Without Storage and Delivery Mechanism
Years 2027 through 2060

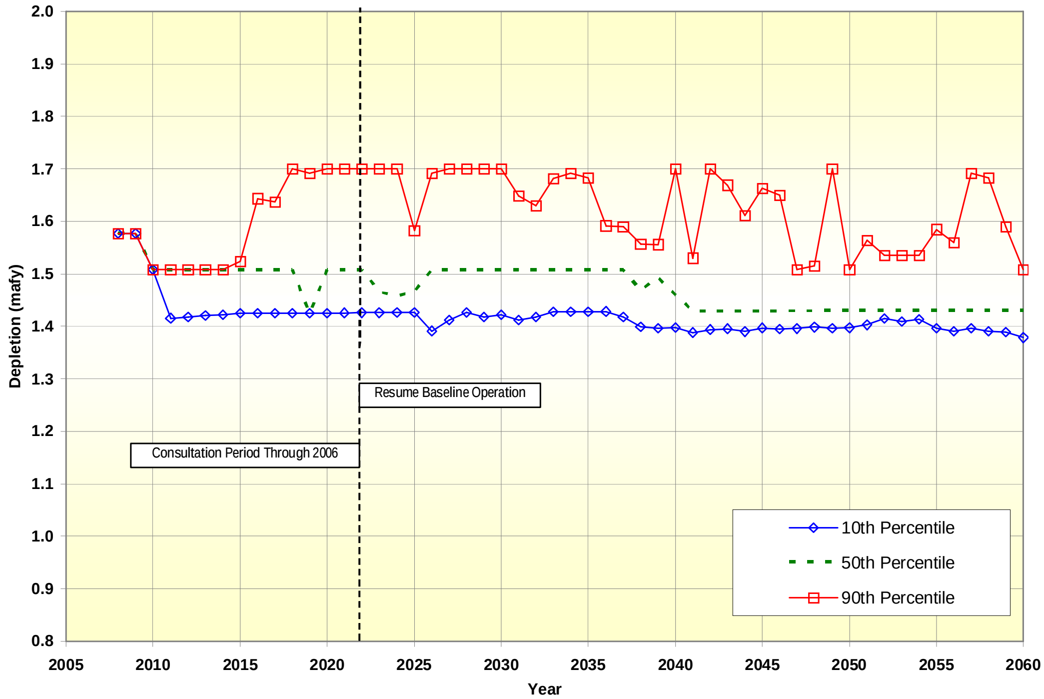


4.4.6 Water Deliveries to Mexico

This section presents the simulated water deliveries to Mexico under the No Action Alternative and the action alternatives. The model assumes a delivery to Mexico of 1.5 mafy with additional deliveries of up to 200 kaf when Lake Mead is in flood control operations. Reductions in deliveries to Mexico are simulated consistent with the modeling assumptions noted in Section 2.2, Section 4.2, and Appendix A. Reclamation's modeling assumptions are not intended to constitute an interpretation or application of the 1944 Treaty or to represent current United States policy or a determination of future United States policy regarding deliveries to Mexico. The sensitivity of water deliveries to Mexico and other hydrologic variables (e.g., Lake Mead elevation) to these modeling assumptions was analyzed and the results of this analysis are presented in Appendix Q.

No Action Alternative. Water deliveries to Mexico are projected to fluctuate throughout the 53-year period of analysis reflecting variations in hydrologic conditions. The 90th, 50th, and 10th percentile ranking of modeled water deliveries to Mexico under the No Action Alternative are presented in Figure 4.4-35. Since the No Action Alternative does not include a storage and delivery mechanism, deviations from annual deliveries of 1.5 mafy are due to the modeling assumptions with respect to water delivery reductions and additional deliveries to Mexico as described in Section 2.2, Section 4.2, and Appendix A.

Figure 4.4-35
Mexico Modeled Annual Depletions
No Action Alternative
90th, 50th, and 10th Percentile Values



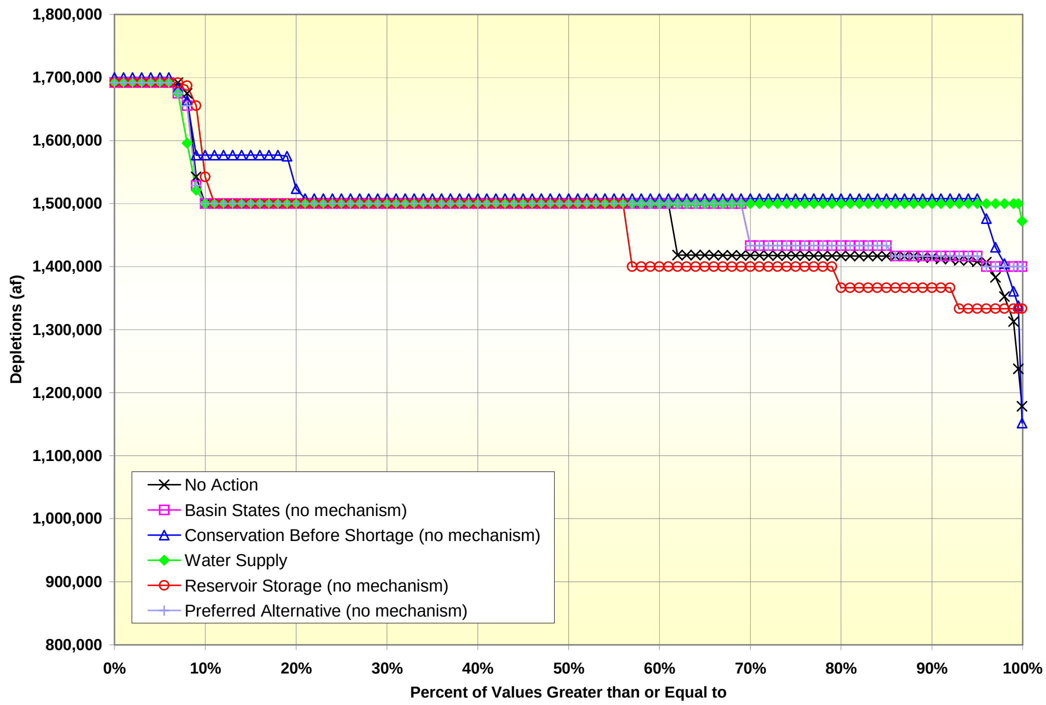
The upper range of 90th percentile annual depletion values shown on Figure 4.4-35 generally coincides with Mexico's depletion schedule during Lake Mead flood control operations. The 90th percentile values fluctuate between 1.5 mafy to 1.7 mafy between 2008 through 2060.

The 50th percentile line represents the median annual depletion values (1.5 mafy) from 2008 through 2018. After 2018, the 50th percentile annual depletion values fluctuate between 1.425 maf and 1.5 maf. The drop in the modeled water deliveries to Mexico below Mexico's 1.5 maf allotment reflects the modeling assumptions with respect to reductions in water deliveries.

The 10th percentile line coincides with the median annual depletion values (1.5 mafy) from 2008 through 2009 and falls to 1.416 mafy in 2011. After 2011, the annual depletion values fluctuate between 1.378 mafy and 1.428 mafy. The drop in the modeled water deliveries to Mexico below Mexico's 1.5 maf allotment reflects the modeling assumptions with respect to reductions in water deliveries.

Comparison of Action Alternatives Without the Storage and Delivery Mechanism to No Action Alternative. Figure 4.4-36 provides a comparison of the cumulative distribution of Mexico's depletions under the action alternatives without the storage and delivery mechanism to those of the No Action Alternative during the interim period, 2008 through 2026. The results presented in Figure 4.4-36 can be used to compare how often Mexico might expect deliveries above and below its 1944 Treaty allocation of 1.5 mafy under the different alternatives. The occurrences of deliveries greater than 1.5 mafy reflect times when Hoover Dam is under flood control operations (Mexico can order additional water up to 1.7 mafy).

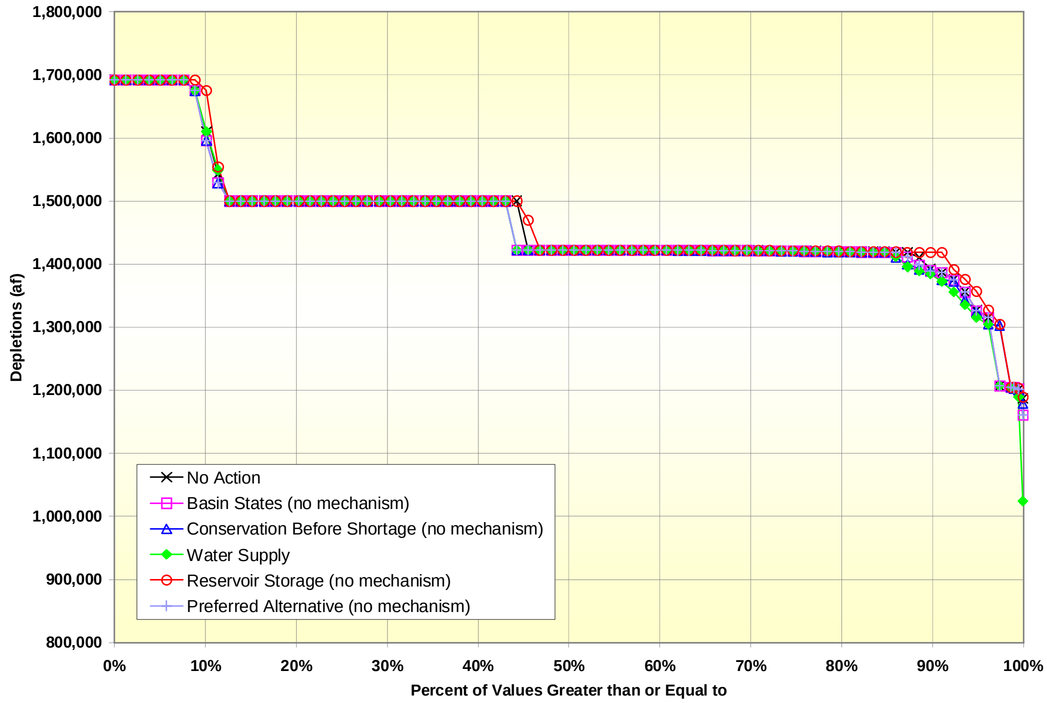
Figure 4.4-36
Mexico Modeled Annual Depletions
Comparison of Action Alternatives (Without Storage and Delivery Mechanism) to No Action Alternative
Years 2008 through 2026



The occurrences of deliveries less than 1.5 mafy reflect the modeling assumptions with regard to reductions in water deliveries to Mexico (Section 2.2 and Appendix Q).

Figure 4.4-37 provides a similar comparison of the cumulative distribution of the water deliveries to Mexico under the action alternatives without the storage and delivery mechanism to those of the No Action Alternative for the 34-year period, years 2027 through 2060, that would follow the interim period.

Figure 4.4-37
Mexico Modeled Annual Depletions
Comparison of Action Alternatives With and Without Storage and Delivery Mechanism
Years 2027 through 2060



4.4.7 Distribution of Shortages to and within the Lower Division States

Although the Consolidated Decree and the CRBPA provide some direction to the Secretary with regard to the distribution of shortages to the Lower Division states, no specific guidelines exist with regard to exactly how those shortages would be distributed. Furthermore, although priority systems exist within each state, exactly how shortages would be distributed to water users of equal priority within a state is unknown. Therefore, specific modeling assumptions were made in order to facilitate the comparison of each alternative. These assumptions, discussed in Section 4.2, Appendix A, and Appendix G are consistent among all alternatives.

Total Lower Basin shortages of 200 kaf to 2.5 maf were analyzed to consider how shortages within this range would be distributed among and within the Lower Division states. Because the shortage sharing assumptions are identical under all alternatives, the distribution of the shortage volumes would be identical under the different alternatives. The factor that changes is the probability or frequency that the different shortage volumes would occur under the different alternatives.

Table 4.4-12 and Table 4.4-13 provide the probability of occurrence of the total Lower Basin shortage volumes that are less than or equal to those shown in Table 4.4-12 for two periods, 2008 through 2026 and 2027 through 2060, respectively. The probability of shortages with a magnitude of zero includes periods when a Surplus Condition or a Normal Condition are in effect.

Table 4.4-12
Probability of Occurrence of Shortages Less Than or Equal to, Years 2008 through 2026 (percent)

Alternative	Total Voluntary or Involuntary Lower Basin Shortage (af)									
	0	200,000	400,000	500,000	600,000	800,000	1,000,000	1,200,000	1,800,000	2,500,000
No Action	61.6	61.6	61.6	86.4	96.3	97.5	98.5	99.3	99.8	100.0
Basin States	73.7	73.7	88.5	96.5	99.4	100.0	100.0	100.0	100.0	100.0
Conservation Before Shortage	75.8	76.2	90.4	97.3	98.3	99.2	99.7	99.8	99.8	100.0
Water Supply	96.5	98.4	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Reservoir Storage	66.9	66.9	66.9	66.9	87.4	97.6	97.6	100.0	100.0	100.0
Preferred Alternative	78.9	78.9	91.4	97.3	99.7	100.0	100.0	100.0	100.0	100.0

Table 4.4-13
Probability of Occurrence of Shortages Less Than or Equal to, Years 2027 through 2060 (percent)

Alternative	Total Voluntary or Involuntary Lower Basin Shortage (af)									
	0	200,000	400,000	500,000	600,000	800,000	1,000,000	1,200,000	1,800,000	2,500,000
No Action	44.59	44.59	44.59	88.26	89.21	93.03	94.35	96.62	99.59	100.00
Basin States	44.44	44.44	44.44	88.71	89.59	93.15	94.62	96.59	99.12	100.00
Conservation Before Shortage	44.47	44.47	44.47	86.71	89.12	92.44	93.88	97.97	99.74	100.00
Water Supply	43.94	43.94	43.94	85.85	86.97	91.29	93.76	96.15	99.21	99.85
Reservoir Storage	46.82	46.82	46.82	93.94	94.35	95.35	96.71	97.74	100.00	100.00
Preferred Alternative	44.50	44.50	44.50	88.85	89.79	93.47	94.71	96.82	99.18	100.00

4.4.7.1 Distribution of Shortages within Arizona

Table 4.4-14 provides Lower Basin shortage volumes up to 2.5 maf and the portions of these shortage amounts that were assumed to be distributed to Arizona. This table shows the shortage distribution in different years because the distribution changes at the higher magnitudes of shortage due to the changes in the scheduled use of the Arizona 4th Priority water users (Appendix G).

Table 4.4-14
Shortage Allocation to Arizona (af)

Year	Total Lower Basin Shortage								
	200,000	400,000	500,000	600,000	800,000	1,000,000	1,200,000	1,800,000	2,500,000
2008	160,000	320,000	400,000	480,000	640,000	800,000	960,000	1,440,000	1,587,484
2017	160,000	320,000	400,000	480,000	640,000	800,000	960,000	1,397,578	1,533,925
2026	160,000	320,000	400,000	480,000	640,000	800,000	960,000	1,394,205	1,530,879
2027	160,000	320,000	400,000	480,000	640,000	800,000	960,000	1,393,837	1,530,547
2040	160,000	320,000	400,000	480,000	640,000	800,000	960,000	1,388,281	1,525,531
2060	160,000	320,000	400,000	480,000	640,000	800,000	960,000	1,388,281	1,525,531

Under most circumstances, the probabilities of involuntary and voluntary shortages being allocated to Arizona are the same as the probability of shortage allocations to the Lower Basin under the No Action Alternative for each of the action alternatives. The overall probabilities are presented in Table 4.4-12 and Table 4.4-13. Table 4.4-15 presents the maximum observed reductions in water deliveries to Arizona under the No Action Alternative and the five action alternatives for selected years.

Table 4.4-15
Maximum Observed Reductions in Water Deliveries to Arizona for Selected Years (af)

Year	No Action	Basin States	Conservation Before Shortage	Water Supply	Reservoir Storage	Preferred Alternative
2008	0	0	0	0	0	0
2017	852,769	480,000	789,937	0	800,000	480,000
2026	1,397,415	480,000	1,414,524	0	800,000	480,000
2027	1,397,227	1,437,602	1,394,487	1,599,660	390,915	663,773
2040	1,381,742	1,390,718	1,383,204	1,424,813	1,384,344	1,392,854
2060	1,401,001	1,389,377	1,386,026	1,401,001	1,385,800	1,389,377

While shortage allocations to California and Nevada would affect single entities within each state (MWD in California and SNWA in Nevada) allocations within Arizona are distributed among a number of water users based upon Arizona's system of water rights priorities and recommendations provided by ADWR during the public comment period (Section 3.4 and Appendix G). This shortage distribution does not reflect management decisions that may be taken by Arizona entities to obtain additional water supplies to offset shortages. Tables 4.4-16 through 4.4-20 summarize how shortages of different volumes in Arizona would be distributed among Arizona's priorities and how this distribution changes over time. These tables do not show 5th priority users and the CAP Bank who now rely on unused and surplus water because the assumption is that by 2017, no unused water will be available to the 5th priority users.

The allocation of shortages to individual users within the CAP is affected by the water priority system within the CAP, the AWSA, and the water use buildup schedules for the CAP users. A major change in the allocation of Arizona shortages within the CAP occurs during the period between 2017 and 2040 and can be seen in Table 4.4-16 through Table 4.4-19. Over time, the impact of a given shortage to the CAP increasingly impacts the higher priority Indian and M&I users as their use builds up, and the shortage cannot be absorbed by the lower priorities.

Prior to the enactment of the AWSA, there were differing views as to how smaller shortages would be distributed between the CAP Indian and M&I priority users. As part of the AWSA, a compromise was reached. Also, under the AWSA, the CAP irrigation districts agreed to relinquish their long-term water service subcontracts for Non-Indian Agricultural priority water. Approximately 300 kaf was relinquished, with approximately 200 kaf being made available for Indian water rights settlements and approximately 100 kaf being made available for future M&I use. In return, the irrigation districts obtained CAP distribution system debt relief, relief from the acreage limitation provisions of federal Reclamation law, and a commitment from the CAP to receive an interim water supply at an affordable rate.

Table 4.4-16
Distribution of Shortages Among Arizona Entities[1] (af), Year 2017

Lower Basin Shortage Allocations	200,000	400,000	500,000	600,000	800,000	1,000,000	1,200,000	1,800,000	2,500,000
Surplus Contracts	0	0	0	0	0	0	0	0	0
4th Priority (River Users)	6,222	14,019	17,921	21,862	30,992	40,787	50,788	79,350	79,350
4th Priority (CAP)	153,778	305,981	382,079	458,138	609,008	759,213	909,212	1,304,575	1,304,575
CAP 5: Arizona Ground Water Bank	0	0	0	0	0	0	0	0	0
CAP 4: Excess Water for Agriculture	146,088	277,891	277,891	277,891	277,891	277,891	277,891	277,891	277,891
CAP 3: Agriculture	0	998	6,637	9,026	9,026	9,026	9,026	9,026	9,026
CAP 3: Tribes	0	2,576	17,134	23,300	23,300	23,300	23,300	23,300	23,300
CAP 3: M&I	0	9,216	61,311	83,375	83,375	83,375	83,375	83,375	83,375
CAP 2: Tribes	0	0	0	40,488	92,623	144,529	196,363	328,486	328,486
CAP 2: M&I	0	0	0	1,150	92,341	183,130	273,795	512,767	512,767
2nd/3rd Priority (includes CAP 1)	0	0	0	0	0	0	0	13,653	149,999
CAP 1: Tribes	0	0	0	0	0	0	0	1,064	11,691
CAP 1: M&I	0	0	0	0	0	0	0	468	5,144
1st Priority (PPR's)	0	0	0	0	0	0	0	0	0

1 CAP users incur five percent conveyance loss through the CAP system due to seepage and therefore the sum of the Arizona shortages in any one column do not add up to the total shortage volume allocated to Arizona at each Lower Basin Shortage increment noted at the top of the table.

Table 4.4-17
Distribution of Shortages Among Arizona Entities[1] (af), Year 2026

Lower Basin Shortage Allocations	200,000	400,000	500,000	600,000	800,000	1,000,000	1,200,000	1,800,000	2,500,000
Surplus Contracts	0	0	0	0	0	0	0	0	0
4th Priority (River Users)	6,816	14,647	18,565	23,334	33,166	43,041	53,173	81,629	81,629
4th Priority (CAP)	153,184	305,353	381,435	456,666	606,834	756,959	906,827	1,297,791	1,297,791
CAP 5: Arizona Ground Water Bank	0	0	0	0	0	0	0	0	0
CAP 4: Excess Water for Agriculture	72,075	72,075	72,075	72,075	72,075	72,075	72,075	72,075	72,075
CAP 3: Agriculture	2,694	7,998	9,026	9,026	9,026	9,026	9,026	9,026	9,026
CAP 3: Tribes	37,477	111,238	125,540	125,540	125,540	125,540	125,540	125,540	125,540
CAP 3: M&I	33,278	98,774	111,474	111,474	111,474	111,474	111,474	111,474	111,474
CAP 2: Tribes	0	0	26,494	50,582	102,474	154,352	206,141	336,744	336,744
CAP 2: M&I	0	0	17,754	65,136	155,903	246,644	337,229	573,541	573,541
2nd/3rd Priority (includes CAP 1)	0	0	0	0	0	0	0	14,785	151,460
CAP 1: Tribes	0	0	0	0	0	0	0	1,137	11,646
CAP 1: M&I	0	0	0	0	0	0	0	500	5,124
1st Priority (PPR's)	0	0	0	0	0	0	0	0	0

1 CAP users incur five percent conveyance loss through the CAP system due to seepage and therefore the sum of the Arizona shortages in any one column do not add up to the total shortage volume allocated to Arizona at each Lower Basin Shortage increment noted at the top of the table.

Table 4.4-18
Distribution of Shortages Among Arizona Entities[1] (af), Year 2027

Lower Basin Shortage Allocations	200,000	400,000	500,000	600,000	800,000	1,000,000	1,200,000	1,800,000	2,500,000
Surplus Contracts	0	0	0	0	0	0	0	0	0
4th Priority (River Users)	6,819	14,654	18,650	23,477	33,313	43,199	53,339	81,782	81,782
4th Priority (CAP)	153,181	305,346	381,350	456,523	606,687	756,801	906,661	1,297,146	1,297,146
CAP 5: Arizona Ground Water Bank	0	0	0	0	0	0	0	0	0
CAP 4: Excess Water for Agriculture	33,158	33,158	33,158	33,158	33,158	33,158	33,158	33,158	33,158
CAP 3: Agriculture	3,672	8,397	9,026	9,026	9,026	9,026	9,026	9,026	9,026
CAP 3: Tribes	63,334	144,815	155,660	155,660	155,660	155,660	155,660	155,660	155,660
CAP 3: M&I	45,356	103,707	111,474	111,474	111,474	111,474	111,474	111,474	111,474
CAP 2: Tribes	0	0	27,546	51,672	103,564	155,438	207,224	337,661	337,661
CAP 2: M&I	0	0	25,417	72,705	163,470	254,204	344,785	580,808	580,808
2nd/3rd Priority (includes CAP 1)	0	0	0	0	0	0	0	14,909	151,620
CAP 1: Tribes	0	0	0	0	0	0	0	1,144	11,637
CAP 1: M&I	0	0	0	0	0	0	0	503	5,120
1st Priority (PPR's)	0	0	0	0	0	0	0	0	0

1 CAP users incur five percent conveyance loss through the CAP system due to seepage and therefore the sum of the Arizona shortages in any one column do not add up to the total shortage volume allocated to Arizona at each Lower Basin Shortage increment noted at the top of the table.

Table 4.4-19
Distribution of Shortages Among Arizona Entities[1] (af), Year 2040

Lower Basin Shortage Allocations	200,000	400,000	500,000	600,000	800,000	1,000,000	1,200,000	1,800,000	2,500,000
Surplus Contracts	0	0	0	0	0	0	0	0	0
4th Priority (River Users)	6,866	14,920	19,748	24,620	34,508	44,530	55,355	85,403	85,403
4th Priority (CAP)	153,134	305,080	380,252	455,380	605,492	755,470	904,645	1,286,087	1,286,087
CAP 5: Arizona Ground Water Bank	0	0	0	0	0	0	0	0	0
CAP 4: Excess Water for Agriculture	0	0	0	0	0	0	0	0	0
CAP 3: Agriculture	3,600	5,937	5,937	5,937	5,937	5,937	5,937	5,937	5,937
CAP 3: Tribes	86,201	142,140	142,140	142,140	142,140	142,140	142,140	142,140	142,140
CAP 3: M&I	55,675	91,804	91,804	91,804	91,804	91,804	91,804	91,804	91,804
CAP 2: Tribes	0	12,705	30,871	56,016	107,890	159,717	211,266	338,579	338,579
CAP 2: M&I	0	37,240	90,488	136,714	227,447	318,099	408,266	638,823	638,823
2nd/3rd Priority (includes CAP 1)	0	0	0	0	0	0	0	16,791	154,042
CAP 1: Tribes	0	0	0	0	0	0	0	1,270	11,647
CAP 1: M&I	0	0	0	0	0	0	0	559	5,125
1st Priority (PPR's)	0	0	0	0	0	0	0	0	0

1 CAP users incur five percent conveyance loss through the CAP system due to seepage and therefore the sum of the Arizona shortages in any one column do not add up to the total shortage volume allocated to Arizona at each Lower Basin Shortage increment noted at the top of the table.

Table 4.4-20
Distribution of Shortages Among Arizona Entities[1] (af), Year 2060

Lower Basin Shortage Allocations	200,000	400,000	500,000	600,000	800,000	1,000,000	1,200,000	1,800,000	2,500,000
Surplus Contracts	0	0	0	0	0	0	0	0	0
4th Priority (River Users)	7,410	16,857	22,049	27,285	37,903	48,700	59,645	89,740	89,740
4th Priority (CAP)	152,590	303,143	377,951	452,715	602,097	751,300	900,355	1,281,750	1,281,750
CAP 5: Arizona Ground Water Bank	0	0	0	0	0	0	0	0	0
CAP 4: Excess Water for Agriculture	0	0	0	0	0	0	0	0	0
CAP 3: Agriculture	4,123	5,359	5,359	5,359	5,359	5,359	5,359	5,359	5,359
CAP 3: Tribes	98,701	128,312	128,312	128,312	128,312	128,312	128,312	128,312	128,312
CAP 3: M&I	42,162	54,811	54,811	54,811	54,811	54,811	54,811	54,811	54,811
CAP 2: Tribes	0	18,528	31,742	56,594	108,215	159,775	211,283	338,579	338,579
CAP 2: M&I	0	81,000	138,854	185,028	275,320	365,503	455,597	686,126	686,126
2nd/3rd Priority (includes CAP 1)	0	0	0	0	0	0	0	16,791	154,042
CAP 1: Tribes	0	0	0	0	0	0	0	1,270	11,647
CAP 1: M&I	0	0	0	0	0	0	0	559	5,125
1st Priority (PPR's)	0	0	0	0	0	0	0	0	0

1 CAP users incur five percent conveyance loss through the CAP system due to seepage and therefore the sum of the Arizona shortages in any one column do not add up to the total shortage volume allocated to Arizona at each Lower Basin Shortage increment noted at the top of the table.

4.4.7.2 Distribution of Shortages within California

This section provides a discussion of how shortages that are allocated to California are distributed to the Colorado River water entitlement holders, based on the shortage sharing assumptions programmed into the Shortage Allocation Model.

The distribution or allocation of California shortages among California's Colorado River water entitlement holders is based on California's system of water entitlement priorities. Of particular note is the frequency and magnitude of the shortages that are allocated to California. Because California's deliveries are not affected by Stage 1 shortages (Section 4.2), the total Lower Basin shortage has to exceed approximately 1.7 maf before deliveries to California are affected. As a result of this, California receives less frequent shortages than Arizona and Nevada, and the magnitude of shortages to California are smaller in proportion to the total Lower Basin shortage, as compared to those of Arizona.

Table 4.4-21 provides an overview of the portion of the total Lower Basin shortage that is allocated to California. As shown on this table, only Stage 2 shortages (Section 4.2) affect California water deliveries. A Stage 2 shortage would occur if the total Lower Basin shortage exceeds 1.83 maf in year 2008. This threshold decreases to 1.72 maf in 2060.

Table 4.4-21
Shortage Allocation to California (af)

Lower Basin Shortage Allocations	200,000	400,000	500,000	600,000	800,000	1,200,000	1,800,000	2,500,000
Shortage allocation to California – 2008	0	0	0	0	0	0	0	409,516
Shortage allocation to California – 2017	0	0	0	0	0	0	39,422	462,876
Shortage allocation to California – 2026	0	0	0	0	0	0	42,795	465,882
Shortage allocation to California – 2027	0	0	0	0	0	0	43,163	466,210
Shortage allocation to California – 2040	0	0	0	0	0	0	48,719	471,162
Shortage allocation to California – 2060	0	0	0	0	0	0	48,719	471,162

The probability of shortage volumes that are less than or equal to those presented in Table 4.4-21 are presented in Tables 4.4-12 and 4.4-13.

Table 4.4-22 provides the maximum observed reductions in water deliveries to California under the No Action Alternative and the five action alternatives for selected years. Because of the large magnitude of Lower Basin shortages assumed to be required to trigger shortages in California, many shortages declared in the Lower Basin would not trigger water delivery reductions to California.

Table 4.4-22
Maximum Observed Reductions in Water Deliveries to California for Selected Years (af)

Year	No Action	Basin States	Conservation Before Shortage	Water Supply	Reservoir Storage	Preferred Alternative
2008	0	0	0	0	0	0
2017	0	0	0	0	0	0
2026	55,737	0	108,730	0	0	0
2027	56,659	181,672	48,176	683,502	0	0
2040	31,578	59,225	36,082	164,243	39,592	65,806
2060	90,899	55,096	44,773	90,899	44,077	55,096

The maximum observed reductions in water deliveries presented in Table 4.4-22 for California vary with both the maximum level of declared shortage in the Lower Basin and with the timing of the shortage. Under almost all conditions, the California shortage is allocated to the MWD. However, for the maximum shortage analyzed (2.94 maf, which occurs less than one percent of the time under the Water Supply Alternative), the shortage allocated to California would include a very small portion of shortage (15,464 af) that would be allocated to other California users. Due to the observed low probability of occurrence of reductions in water deliveries to California of this magnitude, further analysis was not considered to be warranted.

4.4.7.3 Distribution of Shortages to Nevada

Table 4.4-23 shows different Lower Basin shortage volumes and the portion of the shortage that is allocated to Nevada. The shortage allocation to Nevada represents approximately 3.33 percent of the total Lower Basin shortage amount. This percentage does not vary with time and is distributed among users served by the SNWA.

Table 4.4-23
Shortage Allocation to Nevada (af)

Lower Basin Shortage Allocations	200,000	400,000	500,000	600,000	800,000	1,200,000	1,800,000	2,500,000
Shortage allocation to Nevada	6,667	13,333	16,667	20,000	26,667	40,000	60,000	83,333

The probability of occurrence of shortage volumes that are less than or equal to those presented in Table 4.4-23 are presented in Tables 4.4-12 and 4.4-13.

Table 4.4-24 provides the maximum observed reductions in water deliveries to Nevada under the No Action Alternative and five action alternatives for selected years.

Table 4.4-24
Maximum Observed Reductions in Water Deliveries to Nevada for Selected Years (af)

Year	No Action	Basin States	Conservation Before Shortage	Water Supply	Reservoir Storage	Preferred Alternative
2008	0	0	0	0	0	0
2017	35,532	127,930	32,914	116,530	33,333	20,000
2026	60,548	131,370	63,469	279,000	33,333	105,470
2027	60,579	67,470	60,111	210,547	16,288	27,657
2040	58,888	60,414	59,137	79,338	59,331	60,777
2060	62,163	60,186	59,617	62,163	59,578	60,186

Table 4.4-24 indicates that Nevada receives water delivery reductions greater than the maximum volumes presented in Table 4.4-23 under the Basin States and Water Supply alternatives, and the Preferred Alternative. The larger reductions in water deliveries presented in Table 4.4-24 include reductions to SNWA associated with the physical constraints of SNWA's Lake Mead intake. For example, under the Basin States Alternative, in year 2017, the shortage related water delivery reduction to Nevada is approximately 20,000 af (3.33 percent of the total 600 kaf Lower Basin shortage). However, in the model, Lake Mead elevation is below 1,000 feet msl (the SNWA lower intake elevation) for four months (April through July). During these four months, the model reduces water deliveries to SNWA to zero. The cumulative water delivery reduction to Nevada for this four month period due to the SNWA intake constraints is 107,930 af. Therefore, the maximum observed reductions in water deliveries to Nevada in 2017 under the Basin States Alternative is 127,930 af (20,000 af + 107,930 af = 127,930 af). Similar conditions are observed in Table 4.4-24 under the Basin States Alternative in year 2026; under the Water Supply Alternative in years 2017, 2026, and 2027; and under the Preferred Alternative in year 2026.

4.4.7.4 Water Reductions to Mexico

For modeling purposes, an assumption was made that Mexico's delivery would be reduced below 1.5 mafy when Lower Basin shortages occur (Section 4.2). The amount of the reduction is assumed to be 16.67 percent of the total Lower Basin shortage volume, resulting in a proportional reduction to Mexico equivalent to the proportional reduction to users in the Lower Division States. The portion of the Lower Basin water delivery reductions that are assumed to be assigned to Mexico, based on the aforementioned assumptions, are summarized in Table 4.4-25. The sensitivity of water reductions to Mexico and other hydrologic variables (e.g., Lake Mead elevation) to this modeling assumption was analyzed and the results of this analysis are presented in Appendix Q.

Table 4.4-25
Water Reductions to Mexico[1] (af)

Lower Basin Shortage Allocations	200,000	400,000	500,000	600,000	800,000	1,200,000	1,800,000	2,500,000
Water reduction to Mexico	33,333	66,667	83,333	100,000	133,333	200,000	300,000	416,667

1. These modeling assumptions do not reflect policy decisions and are not intended to constitute an interpretation or application of the 1944 Treaty.

The probability of water reductions to Mexico are the same as the probability of Lower Basin shortage. The probability of shortage volumes that are less than of equal to those presented in Table 4.4-25 under the No Action Alternative and for each of the action alternatives are presented in Tables 4.4-13 and 4.4-14.

Table 4.4-25 indicates that, while the proportion of the Lower Basin shortage distributed to Mexico is constant, the probability of the occurrence of water reduction increases over time. Table 4.4-26 provides the maximum observed reductions of water deliveries to Mexico under the No Action Alternative and the five action alternatives for selected years.

Table 4.4-26
Maximum Observed Reductions in Water Deliveries to Mexico[1] for Selected Years (af)

Year	No Action	Basin States	Conservation Before Shortage	Water Supply	Reservoir Storage	Preferred Alternative
2008	0	0	0	0	0	0
2017	177,660	100,000	164,570	0	166,667	100,000
2026	302,740	100,000	317,344	0	166,667	100,000
2027	302,893	337,349	300,555	475,663	81,441	138,286
2040	294,442	302,071	295,685	331,053	296,653	303,887
2060	310,813	300,932	298,083	310,813	297,891	300,932

1. These modeling assumptions do not reflect policy decisions and are not intended to constitute an interpretation or application of the 1944 Treaty.

4.4.8 Summary

The following conclusions may be drawn from the analyses of water deliveries.

4.4.8.1 Normal Conditions

All of the action alternatives increase the probability that normal deliveries will be met over the interim period relative to the No Action Alternative. The differences between the action alternatives and the No Action Alternative, in terms of the probability of occurrence for water supply deliveries under a Normal Condition, begin to diminish after 2027 and are nearly zero by about 2038.

4.4.8.2 Surplus Conditions

The Water Supply Alternative exhibits the same probability of surplus deliveries as the No Action Alternative (between about 30 to 40 percent) between 2008 and 2016 due to identical assumptions regarding surplus during this period. The ISG provisions terminate under the No Action Alternative in 2016. However, these provisions are retained in the Water Supply Alternative through 2026 and therefore this alternative consistently provides the highest probability of surplus deliveries during the interim period. The Reservoir Storage Alternative exhibits the lowest probabilities (between about ten to 20 percent) during the interim period because surplus determinations are limited to Quantified and Flood Control Surplus Conditions beginning in 2008. The surplus provisions under the Basin States and the Conservation Before Shortage Alternatives, and under the Preferred Alternative, are similar and the probability of a Surplus Condition from 2010 through 2016 is slightly less than under the No Action Alternative due to the absence of the Partial Domestic Surplus provision in these three alternatives. After the end of the interim period in 2026, the probability for all alternatives converges to between ten and 20 percent.

The storage and delivery mechanism and related storage and delivery of conserved system and non-system water were modeled under the Basin States, Conservation Before Shortage, and Reservoir Storage Alternatives, and the Preferred Alternative. This modeling assumption has the effect of increasing the probability of occurrence of a Surplus Condition. The maximum increase in the probability of occurrence of a Surplus Condition is seven percent, occurring in two years under the Preferred Alternative.

4.4.8.3 Shortage Conditions

During most of the interim period, the probability of involuntary and voluntary shortage is less under all of the action alternatives than under the No Action Alternative. The probability of occurrence of shortages under the Water Supply Alternative is less than under the No Action Alternative and the other action alternatives during the interim period because reductions in water deliveries under the Water Supply Alternative only occur if Lake Mead's elevation is below 1,000 (the minimum elevation for operation of SNWA's lower intake) or if Lake Mead is drawn down to the top of its dead pool elevation (895 feet msl). However, after 2026, the Water Supply Alternative has the highest probability of shortage due to the depleted storage conditions and the assumption that the operations revert back to the criteria used in the modeling of the No Action Alternative after 2026. In terms of magnitude, the average shortages that occur under the Water Supply Alternative (zero and 240 kafy) are significantly less than those observed under the No Action Alternative (500 and 610 kafy) during the interim period. After 2026, higher average and maximum shortage volumes are observed under the Water Supply Alternative relative to the No Action Alternative and the other action alternatives.

The probability of occurrence of shortages under the Reservoir Storage Alternative is slightly higher than under the No Action Alternative between 2008 and 2013. However, after 2013 and through about 2037, shortages under the Reservoir Storage Alternative occur less frequently as compared to the No Action Alternative. In terms of magnitude, the average shortage volumes that are observed during the interim period are highest under the Reservoir Storage Alternative (between 600 and 750 kafy). This occurs because the Reservoir Storage Alternative contains the most aggressive shortage strategy that applies shortages starting at higher elevations in Lake Mead and at higher magnitudes.

Shortages also occur less frequently under the Basin States and Conservation Before Shortage Alternatives, and the Preferred Alternative during the interim period as compared to the No Action Alternative and are similar after 2026. The Preferred Alternative also shows somewhat lower probabilities (up to approximately ten percent) of shortages over the entire interim period when compared to the Basin States and Conservation Before Shortage Alternatives. In terms of magnitude, the average shortages that are observed under the Basin States and Conservation Before Shortage Alternatives, and the Preferred Alternative are similar to each other (between 400 and 530 kafy) and are less than those observed under the No Action Alternative during the interim period.

Multi-year shortages with annual shortage volumes equal to or greater than 400 kaf are likely for all alternatives with the exception of the Water Supply Alternative, with the Conservation Before Shortage Alternative and the Preferred Alternative exhibiting probabilities of between ten and 30 percent over the interim period for durations of two or more years. Multi-year shortages with annual shortage volumes equal to or greater than 500 kafy are most likely for the Reservoir Storage Alternative with probabilities of approximately 35 percent for durations of two or more years and 26 percent for durations of five or more years. Multi-year shortages with annual shortage volumes equal to or greater than 600 kafy are likely only for the Reservoir Storage Alternative. No alternatives exhibited shortages of greater than or equal to 1.0 mafy for any duration.

The mechanism to deliver and store conserved system and non-system water assumed as part of the Basin States, Conservation Before Shortage, and Reservoir Storage Alternatives, and under the Preferred Alternative has the effect of decreasing the occurrence of shortages. Due to the assumptions of increased participation in the storage and delivery mechanism, the greatest differences (up to a ten percent reduction in shortage probability during the interim period) were observed under the Reservoir Storage Alternative and under the Preferred Alternative.

4.5 Water Quality

4.5.1 Introduction

This section describes the methods used to determine the potential effects to water quality associated with each alternative considered in the proposed federal action, and discusses the results of these analyses.

4.5.2 Methodology

The salinity module of the CRSS RiverWare™ model was used to analyze changes in salinity concentration under each of the alternatives for Colorado River reaches from Lake Powell to Imperial Dam.

Using the hydrologic output from CRSS, the CE-QUAL-W2 model was used to simulate temperatures of Lake Powell releases, and the Generalized Environmental Modeling System for Surfacewater (GEMSS) was used to simulate river temperatures between Glen Canyon Dam and Lake Mead for each of the alternatives. Detailed descriptions of these models are provided in Appendix F. Qualitative assessments of other water quality parameters in Lake Powell were based on historical data.

For all parameters other than salinity, the analysis of potential impacts to Lake Mead water quality were based on a combination of detailed water quality modeling and analysis conducted for the SCOP FEIS (Clean Water Coalition 2006), and historical data. Modeling for the SCOP FEIS analyzed the potential effects on water quality as a result of rerouting effluent from Las Vegas Wash to Lake Mead's Boulder Basin via a pipeline. The modeling considered lake elevations down to 1,000 feet msl and two levels of total annual average effluent flows: 462 cfs expected by 2030 and 616 cfs expected by 2050. Under the SCOP FEIS preferred alternative referred to as the Boulder Islands North Alternative, impacts to water quality are considered to be insignificant and negligible with no violation of drinking water regulations for Lake Mead elevations down to 1,000 feet msl with projected effluent inflow levels for 2025. This information was combined with the probabilities of Lake Mead elevations reaching 1,000 feet msl under the No Action Alternative and the action alternatives considered in this Final EIS to assess potential water quality impacts.

Furthermore, an adaptive management plan for Boulder Basin would be implemented as part of the SCOP preferred alternative. The Boulder Basin Adaptive Management Plan (BBAMP) would establish objectives regarding drinking water quality, downstream water quality, nutrient management, and recreational use including sport fisheries. As part of the BBAMP, water quality parameters would be monitored to establish baseline conditions and analyzed for the need of potential future mitigation measures (Clean Water Coalition 2006).

4.5.2.1 Salinity

Reclamation developed a computational model for salinity to aid in the development of salinity reduction targets for the Colorado River Basin Salinity Control Program (SCP) (Prairie and Callejo 2005). The salinity model simulates the effects of water development projects on future salinity concentration levels in the Colorado River. The model includes future salinity control units that have been authorized for construction but have not yet been completed. The salinity control criteria are purposely designed to be long-term and non-degradational goals, rather than exceedence standards such as those used for industry or drinking water. Efforts of the SCP are designed to meet the criteria by implementing, as needed, the most cost effective salinity control projects. This ensures that the salinity control criteria will continue to be met in the future, even with the salinity impacts produced by increasing Upper Basin depletions.

The data used in the CRSS salinity model are based on a monthly regression of natural flow and salinity data from 1971 through 1995 in the Upper Basin (Prairie and Callejo 2005). The Lower Basin monthly regressions are based on the 1971 through 2005 natural flow and salinity data. The monthly regression models allow extension of the CRSS salinity model data from 1906 through 2005, the period for which natural flow data is available. The CRSS salinity model data includes salinity control levels and salt loading due to agricultural return flows as used in the 2005 Triennial Review (Colorado River Basin Salinity Control Forum 2005). The model simulates annual average salinity concentrations for locations downstream of Hoover Dam and Parker Dam, and at Imperial Dam.

The CRSS salinity model is intended for long-term (15 to 20 years) simulation and it is highly sensitive to initial conditions during the first 10 to 12 years. The model assumes salinity is a conservative water quality parameter, and reservoirs are modeled as fully mixed systems.

4.5.2.2 Temperature

Lake Powell undergoes seasonal transformations that can dramatically affect the temperatures of both the reservoir and Glen Canyon Dam releases. During the spring, solar radiation and warmer air temperatures begin to warm the upper surface layers of the reservoirs. This warming is also affected by spring inflow volumes and temperatures. Larger inflows bring greater volumes of warmer water that can cause higher release temperatures. Reservoir drawdowns can bring the warmer surface water closer to the powerplant intake penstocks, also producing warmer releases. As summer progresses, surface warming of reservoirs increases, as does the warming of releases as the water moves downstream. During the winter months, reservoir temperature stratification is usually eliminated by reservoir mixing, and both reservoir and downstream water cooling occurs. The CE-QUAL-W2 model simulates this annual process and can analyze reservoir and dam release temperatures for various reservoir starting elevations and inflows. The CRSS output of dam release and reservoir elevations was used in the CE-QUAL-W2 model to establish a relationship between reservoir elevations and dam release temperatures and to project the impact of reservoir drawdown on dam release temperatures. Calibration of the CE-QUAL-W2 model for Lake Powell used historic temperature profiles from 1990 through 2005 at 13 reservoir stations.

This 15-year data set provided a limited range of historic reservoir elevations, inflows and releases. By using a combination of historic and modeled data for various reservoir elevations, and by analyzing the impact of a repetition of the recent drought years, dam release temperatures for a larger range of reservoir elevations could be analyzed.

The GEMSS used the Glen Canyon Dam release temperatures to model downstream temperatures through Grand Canyon to Lake Mead. The GEMSS model was calibrated for water temperatures at three locations in this river reach: Lees Ferry, 15.9 miles downstream of Glen Canyon Dam; a point one mile downstream of the Little Colorado River confluence; and the Diamond Creek Gaging Station located 240 miles downstream of Glen Canyon Dam. Water temperatures downstream of Diamond Creek approached equilibrium with the ambient air temperature, and the rate of temperature change decreased. Since Lees Ferry temperatures are nearly identical to Glen Canyon Dam release temperatures, only the results for the Little Colorado River confluence and Diamond Creek sites are included in this EIS.

For any specific reservoir starting elevation, there is a range of potential dam release temperatures because the reservoir is affected by the magnitude of spring inflow and summer meteorological conditions. Downstream water temperatures produced by a routing of these releases are also affected by meteorological conditions and the magnitude of dam releases. Thus, for a single reservoir elevation the CE-QUAL-W2 and GEMSS modeling resulted in a range of water temperatures.

The assessment of potential effects of the alternatives on water temperatures in Lake Mead was based on the Lake Mead water quality information provided in the SCOP FEIS.

4.5.2.3 Other Water Quality Parameters

Historic water quality data from Lake Powell and Lake Mead and water quality information from the SCOP FEIS for Lake Mead were used to develop qualitative assessments of potential effects of the alternatives on sediment, nutrients and algae, dissolved oxygen, metals, and perchlorate.

4.5.3 Salinity

Table 4.5-1 presents the SCP salinity control criteria and the CRSS salinity model simulations of salinity concentrations for the years 2008, 2016, 2026, and 2060. The projected salinity concentrations presented are the flow-weighted annual averages for the selected years under the No Action Alternative and the action alternatives. The results assume continuation of existing and implementation of planned salinity control programs and projects. As a result, the flow-weighted annual average salinity concentrations do not increase over time or exceed the SCP salinity control criteria under any of the alternatives for the current plan of implementation, which extends through 2025 (Colorado River Basin Salinity Control Forum 2005). At all times the differences in salinity concentrations among the different alternatives is less than three percent.

Table 4.5-1
Projected Colorado River Salinity (mg/L)[1]
Comparison of Action Alternatives to No Action Alternative

Alternative	Downstream of Hoover Dam SCP Salinity Control Criteria 723 mg/L	Downstream of Parker Dam SCP Salinity Control Criteria 747 mg/L	At Imperial Dam SCP Salinity Control Criteria 879 mg/L
Year 2008			
No Action	639	656	768
Basin States	639	656	773
Conservation Before Shortage	639	656	775
Reservoir Storage	641	658	783
Water Supply	639	656	768
Preferred Alternative	639	657	781
Year 2016			
No Action	596	616	732
Basin States	596	615	732
Conservation Before Shortage	596	616	737
Reservoir Storage	613	623	744
Water Supply	593	612	728
Preferred Alternative	598	618	735
Year 2026			
No Action	602	621	740
Basin States	605	625	747
Conservation Before Shortage	605	625	751
Reservoir Storage	613	633	760
Water Supply	595	615	735
Preferred Alternative	606	625	747
Year 2060			
No Action	625	646	776
Basin States	630	650	782
Conservation Before Shortage	630	650	782
Reservoir Storage	629	650	781
Water Supply	626	646	776
Preferred Alternative	630	650	782

1 CRSS Salinity model simulation of salinity concentration

Salinity of water delivered to Mexico at the NIB pursuant to the 1944 Treaty is limited by Minute 242 (Section 3.5). Accordingly, Minute 242 limits the differential in annual salinity between Imperial Dam and the NIB to 115 ppm (± 30 ppm). Reclamation will continue to take the appropriate actions needed to meet the requirements of Minute 242.

4.5.4 Temperature

4.5.4.1 Lake Powell and Glen Canyon Dam

The release temperature ranges presented in Figure 4.5-1 are comprised of historic and modeled data and represent a yearly range including seasonal fluctuations. This graph shows that as Lake Powell's elevation decreases, the range of annual release temperature fluctuations increases. The minimum release temperatures occur in the winter and are fairly consistent at 7°C to 10°C (44.6ºF to 50ºF). The peak summer release temperature varies significantly with elevation, peaking at about 25°C (77ºF) as the reservoir elevation drops to near the minimum power pool elevation of 3,490 feet msl. The model predicts a wider range of potential temperatures the nearer the reservoir elevation is to the powerplant penstock intakes. Reservoir elevations near the full pool elevation of 3,700 feet msl show much less variation among seasons, with releases consistently cold from 8°C to 12°C (46.4ºF to 53.6ºF). During extreme drought events, the elevation of Lake Powell may drop below the minimum power pool elevation of 3,490 feet msl. If this occurs, releases would be discontinued from the powerplant penstocks and releases would be made through the river outlet tubes, which are located at elevation 3,374 feet msl. Under these conditions, the temperature of water released from Glen Canyon Dam could potentially change from about 25°C to less than 10°C (77ºF to less than 50ºF). If the reservoir elevations were to drop further, closer to the elevation of the river outlet tubes, the releases would again gradually warm.

Figure 4.5 -1
Historic Data and CE-QUAL-W2 Model Results for Lake Powell Release Temperatures by Reservoir Elevation

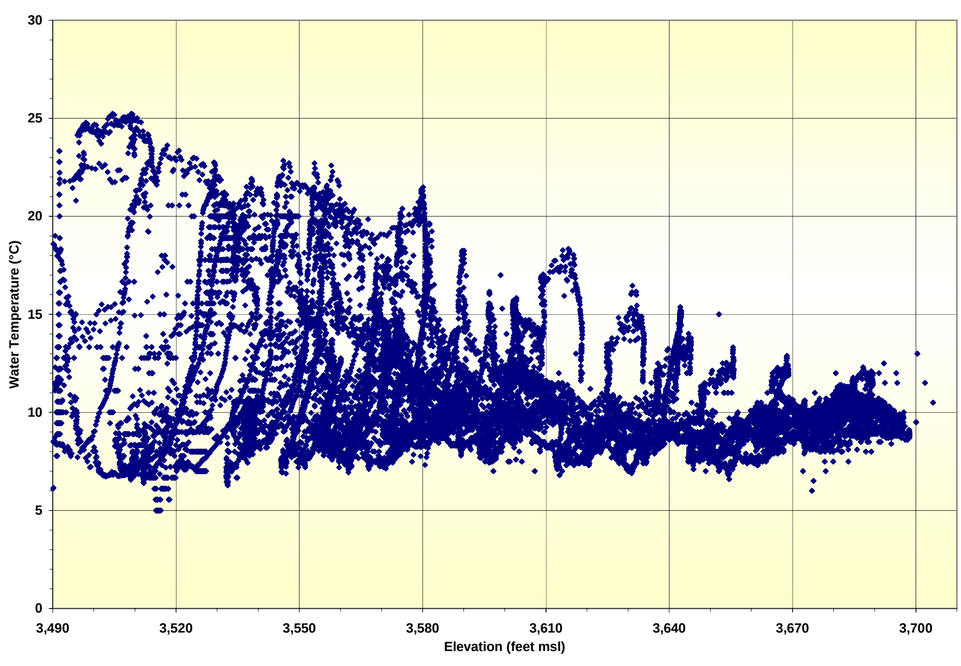


Table 4.5-2 and Table 4.5-3 present projected release temperature ranges associated with the CRSS projected 90th, 50th, and 10th percentile elevations of Lake Powell in 2008, 2016, 2026, and 2060 for the months of July and October, respectively. July and August represent the times of the year when maximum warming occurs in Lake Powell and in Glen Canyon Dam releases. The release temperature ranges in Table 4.5-2 and Table 4.5-3 reflect the variability of hydrologic, meteorological, and hydraulic conditions. The sensitivity of release temperatures to these conditions increases with decreasing reservoir elevations. This sensitivity causes a wide range of possible release temperatures at similar reservoir elevations. In general, for a given month and reservoir elevation, a higher release temperature is associated with an above-average inflow volume and a lower release temperature is associated with a below-average inflow volume. Therefore, the ranges shown in these tables reflect different release temperatures for these specific months and reservoir elevations, ranges which are due primarily to large differences in reservoir inflows.

For reservoir elevations at or above the 90th percentile for all years there are no differences among the alternatives. Overall, the temperature ranges for July and October under the No Action Alternative, Basin States Alternative, Conservation Before Shortage Alternative, and the Preferred Alternative are similar for 2008, 2016, 2026, and 2060 at the 50th and 10th percentiles of reservoir elevations, respectively. The temperature range for the Water Supply Alternative is warmer in 2016 and 2026 due to the corresponding lower Lake Powell reservoir elevations at the 10th and 50th percentiles. The Reservoir Storage Alternative results in cooler water temperatures at the 10th and 50th percentiles of reservoir elevations for some years, due to higher reservoir elevations.

4.5.4.2 Glen Canyon Dam to Lake Mead

Using historic data and output from the CE-QUAL-W2 model as input, the GEMSS model analyzed monthly temperatures for the CRSS at the 90th, 50th, and 10th percentile projected reservoir release flows. Temperatures are presented for each alternative in Table 4.5-4 and Table 4.5-5 for the confluence with the Little Colorado River, and in Table 4.5-6 and Table 4.5-7 for the gage downstream of Diamond Creek for July and October, respectively. The temperature data listed in these tables are averages for each percentile. The projected temperatures vary due to three factors: variable release volume; release temperature ranges; and downstream meteorology. The rate at which the water released from a reservoir approaches ambient air temperature as it travels downstream depends on these factors as well.

Table 4.5-2
Lake Powell End-of-July Elevations and Release Temperatures
Comparison of Action Alternatives to No Action Alternative
90th, 50th, 10th Percentile Values

Alternative	90th Percentile		50th Percentile		10th Percentile	
	Elevation (feet msl)	Temperature (°C)	Elevation (feet msl)	Temperature (°C)	Elevation (feet msl)	Temperature (°C)
Year 2008						
No Action	3,648.3	8.5 to 11.5	3,621.1	8 to 13	3,588.6	9 to 16.5
Basin States	3,645.9	8.5 to 11.5	3,621.1	8 to 13	3,591.7	9 to 16.5
Conservation Before Shortage	3,646.0	8.5 to 11.5	3,621.1	8 to 13	3,591.7	9 to 16.5
Water Supply	3,648.3	8.5 to 11.5	3,621.1	8 to 13	3,592.7	9 to 16.5
Reservoir Storage	3,648.3	8.5 to 11.5	3,621.1	8 to 13	3,590.9	9 to 16.5
Preferred Alternative	3,646.1	8.5 to 11.5	3,621.1	8 to 13	3,591.7	9 to 16.5
Year 2016						
No Action	3,697.9	9 to 11	3,648.1	8.5 to 11.5	3,575.1	10 to 19
Basin States	3,697.9	9 to 11	3,646.0	8.5 to 11.5	3,585.1	9 to 17
Conservation Before Shortage	3,697.9	9 to 11	3,646.0	8.5 to 11.5	3,585.4	9 to 17
Water Supply	3,697.9	9 to 11	3,638.8	8.5 to 11.5	3,560.1	10 to 20
Reservoir Storage	3,698.4	9 to 11	3,650.9	8.5 to 11.5	3,592.7	9 to 16.5
Preferred Alternative	3,697.9	9 to 11	3,646.0	8.5 to 11.5	3,584.3	9 to 17
Year 2026						
No Action	3,698.5	9 to 11	3,659.2	8.5 to 11	3,576.3	10 to 19
Basin States	3,698.3	9 to 11	3,647.6	8.5 to 11.5	3,571.8	10 to 19.5
Conservation Before Shortage	3,698.3	9 to 11	3,647.8	8.5 to 11.5	3,570.9	10 to 19.5
Water Supply	3,698.3	9 to 11	3,629.6	8.5 to 12	3,523.9	17 to 23
Reservoir Storage	3,698.8	9 to 11	3,664.2	8.5 to 11	3,595.9	9 to 16
Preferred Alternative	3,698.3	9 to 11	3,649.3	8.5 to 11.5	3,577.2	10 to 19
Year 2060						
No Action	3,699.2	9 to 11	3,655.9	8.5 to 11	3,565.9	10 to 20
Basin States	3,699.2	9 to 11	3,655.9	8.5 to 11	3,565.9	10 to 20
Conservation Before Shortage	3,699.2	9 to 11	3,655.9	8.5 to 11	3,565.9	10 to 20
Water Supply	3,699.2	9 to 11	3,655.9	8.5 to 11	3,563.7	10 to 20
Reservoir Storage	3,699.2	9 to 11	3,655.9	8.5 to 11	3,565.9	10 to 20
Preferred Alternative	3,699.2	9 to 11	3,655.9	8.5 to 11	3,565.9	10 to 20

Table 4.5-3
Lake Powell End-of-October Elevations and Release Temperatures
Comparison of Action Alternatives to No Action Alternative
90th, 50th, 10th Percentile Values

Alternative	90th Percentile		50th Percentile		10th Percentile	
	Elevation (feet msl)	Temperature (°C)	Elevation (feet msl)	Temperature (°C)	Elevation (feet msl)	Temperature (°C)
Year 2008						
No Action	3,642.0	8.5 to 15	3,613.8	9.5 to 18.5	3,575.3	11 to 21
Basin States	3,641.2	8.5 to 15	3,613.8	9.5 to 18.5	3,577.6	11 to 21
Conservation Before Shortage	3,641.4	8.5 to 15	3,613.8	9.5 to 18.5	3,577.6	11 to 21
Water Supply	3,642.0	8.5 to 15	3,613.8	9.5 to 18.5	3,578.8	11 to 21
Reservoir Storage	3,642.0	8.5 to 15	3,613.8	9.5 to 18.5	3,580.0	11 to 21
Preferred Alternative	3,641.6	8.5 to 15	3,613.8	9.5 to 18.5	3,577.6	11 to 21
Year 2016						
No Action	3,689.6	9 to 11.5	3,642.0	8.5 to 15	3,564.8	12 to 22
Basin States	3,689.6	9 to 11.5	3,637.7	8.5 to 15.5	3,571.4	11 to 21
Conservation Before Shortage	3,689.6	9 to 11.5	3,638.2	8.5 to 15.5	3,571.9	11 to 21
Water Supply	3,689.1	9 to 11.5	3,627.3	8.5 to 17	3,547.6	14 to 22
Reservoir Storage	3,690.0	9 to 11.5	3,647.0	9 to 15	3,585.0	10.5 to 20
Preferred Alternative	3,689.6	9 to 11.5	3,640.5	8.5 to 15	3,572.5	11 to 21
Year 2026						
No Action	3,689.3	9 to 11.5	3,655.7	8.5 to 14	3,567.6	11.5 to 21.5
Basin States	3,689.3	9 to 11.5	3,637.1	8.5 to 15.5	3,562.1	12 to 22
Conservation Before Shortage	3,689.3	9 to 11.5	3,638.4	8.5 to 15.5	3,562.0	12 to 22
Water Supply	3,689.3	9 to 11.5	3,616.9	9.5 to 18	3,501.5	18 to 22.5
Reservoir Storage	3,689.7	9 to 11.5	3,660.3	8.5 to 13	3,590.8	10 to 20
Preferred Alternative	3,689.3	9 to 11.5	3,641.1	8.5 to 15	3,565.0	12 to 22
Year 2060						
No Action	3,689.6	9 to 11.5	3,650.1	8.5 to 14	3,553.0	13 to 22
Basin States	3,689.6	9 to 11.5	3,650.1	8.5 to 14	3,553.0	13 to 22
Conservation Before Shortage	3,689.6	9 to 11.5	3,650.1	8.5 to 14	3,553.0	13 to 22
Water Supply	3,689.6	9 to 11.5	3,650.1	8.5 to 14	3,552.2	13 to 22
Reservoir Storage	3,689.6	9 to 11.5	3,650.1	8.5 to 14	3,553.0	13 to 22
Preferred Alternative	3,689.6	9 to 11.5	3,650.6	8.5 to 14	3,553.0	13 to 22

In general, warmer downstream water temperatures are caused by smaller release volumes, higher release temperatures, and warmer ambient air temperatures. However, the relationship between release temperature and downstream temperature is nonlinear (e.g., a 1°C (1.8ºF) increase in release temperature does not necessarily result in a 1°C (1.8ºF) increase downstream). The temperatures projected for 2008 and 2060 are the same for all alternatives. In 2016 and 2026 the Basin States and Conservation Before Shortage Alternatives, and the Preferred Alternative, have the same projected average temperatures as the No Action Alternative for both October and July at both modeled locations. In general, the Water Supply and Reservoir Storage Alternatives differ from the No Action Alternative in 2016 and 2026 at the 10th and 50th percentile release volumes. The Water Supply Alternative average temperatures are higher than the No Action Alternative's by 0 to 4°C (0 to 7°F). The projected Reservoir Storage Alternative average temperatures are typically 1°C (1.8°F) less than the No Action Alternative temperatures at the 10th and 50th percentiles of river flows due to higher Lake Powell elevations under this alternative.

Table 4.5-4
Colorado River at Little Colorado River Confluence July Water Temperatures
Comparison of Action Alternatives to No Action Alternative
90th, 50th, and 10th Percentile Values

Alternative	90th Percentile		50th Percentile		10th Percentile*	
	Release (maf)	Average Temperature (°C)	Release (maf)	Average Temperature (°C)	Release (maf)	Average Temperature (°C)
Year 2008						
No Action	10.98	12	8.23	13	8.23	18
Basin States	11.22	12	8.23	13	8.23	18
Conservation Before Shortage	11.22	12	8.23	13	8.23	18
Water Supply	10.98	12	8.23	13	8.23	18
Reservoir Storage	10.98	12	8.23	13	7.80	18
Preferred Alternative	11.22	12	8.23	13	8.23	18
Year 2016						
No Action	12.91	11.5	8.23	12	8.23	18
Basin States	13	11.5	9.00	12	8.23	18
Conservation Before Shortage	13.05	11.5	9.00	12	8.23	18
Water Supply	12.67	11.5	9.50	12	8.23	18
Reservoir Storage	13.23	11.5	8.23	12	7.80	17
Preferred Alternative	13.13	11.5	9.00	12	8.23	18
Year 2026						
No Action	12.78	11.5	8.23	12	8.23	18
Basin States	12.69	11.5	9.00	12	8.23	18
Conservation Before Shortage	12.78	11.5	9.00	12	8.23	18
Water Supply	12.73	11.5	9.50	13	8.23	22
Reservoir Storage	12.78	11.5	8.23	12	7.89	16
Preferred Alternative	12.96	11.5	9.00	12	8.23	18
Year 2060						
No Action	12.48	11.5	8.23	12	8.23	18
Basin States	12.48	11.5	8.23	12	8.23	18
Conservation Before Shortage	12.48	11.5	8.23	12	8.23	18
Water Supply	12.48	11.5	8.23	12	8.23	18
Reservoir Storage	12.48	11.5	8.23	12	8.23	18
Preferred Alternative	12.48	11.5	8.23	12	8.23	18

* *Although not indicated for the four years displayed on this table, there are minor differences in monthly average temperatures between the No Action Alternative and the Preferred Alternative at this location. At the 10th percentile, the average monthly temperatures are as much as 1°C warmer under the Preferred Alternative than under the No Action Alternative. These small temperature differences are potentially meaningful in the context of fish habitat (Section 4.8 and Appendix R).*

Table 4.5-5
Colorado River at Little Colorado River Confluence October Water Temperatures
Comparison of Action Alternatives to No Action Alternative
90th, 50th, and 10th Percentile Values

Alternative	90th Percentile		50th Percentile		10th Percentile*	
	Release (maf)	Average Temperature (°C)	Release (maf)	Average Temperature (°C)	Release (maf)	Average Temperature (°C)
Year 2008						
No Action	10.98	13	8.23	13.5	8.23	16
Basin States	11.22	13	8.23	13.5	8.23	16
Conservation Before Shortage	11.22	13	8.23	13.5	8.23	16
Water Supply	10.98	13	8.23	13.5	8.23	16
Reservoir Storage	10.98	13	8.23	13.5	7.80	16
Preferred Alternative	11.22	13	8.23	13.5	8.23	16
Year 2016						
No Action	12.91	10.7	8.23	13	8.23	16
Basin States	13	10.7	9.00	13	8.23	16
Conservation Before Shortage	13.05	10.7	9.00	13	8.23	16
Water Supply	12.67	10.7	9.50	13	8.23	17
Reservoir Storage	13.23	10.7	8.23	12	7.80	16
Preferred Alternative	13.13	10.7	9.00	13	8.23	16
Year 2026						
No Action	12.78	10.7	8.23	13	8.23	16
Basin States	12.69	10.7	9.00	13	8.23	16
Conservation Before Shortage	12.78	10.7	9.00	13	8.23	16
Water Supply	12.73	10.7	9.50	14	8.23	20
Reservoir Storage	12.78	10.7	8.23	12	7.89	16
Preferred Alternative	12.96	10.7	9.00	13	8.23	16
Year 2060						
No Action	12.48	10.7	8.23	13	8.23	16
Basin States	12.48	10.7	8.23	13	8.23	16
Conservation Before Shortage	12.48	10.7	8.23	13	8.23	16
Water Supply	12.48	10.7	8.23	13	8.23	16
Reservoir Storage	12.48	10.7	8.23	13	8.23	16
Preferred Alternative	12.48	10.7	8.23	13	8.23	16

* *Although not indicated for the four years displayed on this table, there are minor differences in monthly average temperatures between the No Action Alternative and the Preferred Alternative at this location. At the 10th percentile, the average monthly temperatures are as much as 1°C warmer under the Preferred Alternative than under the No Action Alternative. These small temperature differences are potentially meaningful in the context of fish habitat (Section 4.8 and Appendix R).*

Table 4.5-6
Colorado River Near Diamond Creek July Water Temperatures
Comparison of Action Alternatives to No Action Alternative
90th, 50th, and 10th Percentile Values

Alternative	90th Percentile		50th Percentile		10th Percentile*	
	Release (maf)	Average Temperature (°C)	Release (maf)	Average Temperature (°C)	Release (maf)	Average Temperature (°C)
Year 2008						
No Action	10.98	18	8.23	19	8.23	21
Basin States	11.22	18	8.23	19	8.23	21
Conservation Before Shortage	11.22	18	8.23	19	8.23	21
Water Supply	10.98	18	8.23	19	8.23	21
Reservoir Storage	10.98	18	8.23	19	7.80	21
Preferred Alternative	11.22	18	8.23	19	8.23	21
Year 2016						
No Action	12.91	17	8.23	18	8.23	21
Basin States	13	17	9.00	18	8.23	21
Conservation Before Shortage	13.05	17	9.00	18	8.23	21
Water Supply	12.67	17	9.50	18	8.23	21
Reservoir Storage	13.23	17	8.23	18	7.80	20
Preferred Alternative	13.13	17	9.00	18	8.23	21
Year 2026						
No Action	12.78	17	8.23	18	8.23	21
Basin States	12.69	17	9.00	18	8.23	21
Conservation Before Shortage	12.78	17	9.00	18	8.23	21
Water Supply	12.73	17	9.50	19	8.23	23
Reservoir Storage	12.78	17	8.23	18	7.89	20
Preferred Alternative	12.96	17	9.00	18	8.23	21
Year 2060						
No Action	12.48	17	8.23	18	8.23	21
Basin States	12.48	17	8.23	18	8.23	21
Conservation Before Shortage	12.48	17	8.23	18	8.23	21
Water Supply	12.48	17	8.23	18	8.23	21
Reservoir Storage	12.48	17	8.23	18	8.23	21
Preferred Alternative	12.48	17	8.23	18	8.23	21

* *Although not indicated for the four years displayed on this table, there are minor differences in monthly average temperatures between the No Action Alternative and the Preferred Alternative at this location. At the 10th percentile, the average monthly temperatures are as much as 1.4°C warmer under the Preferred Alternative than under the No Action Alternative. These small temperature differences are potentially meaningful in the context of fish habitat (Section 4.8 and Appendix R).*

Table 4.5-7
Colorado River Below Diamond Creek October Water Temperatures
Comparison of Action Alternatives to No Action Alternative
90th, 50th, and 10th Percentile Values

Alternative	90th Percentile		50th Percentile		10th Percentile*	
	Release (maf)	Average Temperature (°C)	Release (maf)	Average Temperature (°C)	Release (maf)	Average Temperature (°C)
Year 2008						
No Action	10.98	15	8.23	15	8.23	17
Basin States	11.22	15	8.23	15	8.23	17
Conservation Before Shortage	11.22	15	8.23	15	8.23	17
Water Supply	10.98	15	8.23	15	8.23	17
Reservoir Storage	10.98	15	8.23	15	7.80	17
Preferred Alternative	11.22	15	8.23	15	8.23	17
Year 2016						
No Action	12.91	14	8.23	15	8.23	17
Basin States	13	14	9.00	15	8.23	17
Conservation Before Shortage	13.05	14	9.00	15	8.23	17
Water Supply	12.67	14	9.50	15	8.23	17
Reservoir Storage	13.23	14	8.23	15	7.80	17
Preferred Alternative	13.13	14	9.00	15	8.23	17
Year 2026						
No Action	12.78	14	8.23	15	8.23	17
Basin States	12.69	14	9.00	15	8.23	17
Conservation Before Shortage	12.78	14	9.00	15	8.23	17
Water Supply	12.73	14	9.50	16	8.23	21
Reservoir Storage	12.78	14	8.23	14	7.89	17
Preferred Alternative	12.96	14	9.00	15	8.23	17
Year 2060						
No Action	12.48	14	8.23	15	8.23	17.5
Basin States	12.48	14	8.23	15	8.23	17.5
Conservation Before Shortage	12.48	14	8.23	15	8.23	17.5
Water Supply	12.48	14	8.23	15	8.23	17.5
Reservoir Storage	12.48	14	8.23	15	8.23	17.5
Preferred Alternative	12.48	14	8.23	15	8.23	17.5

* *Although not indicated for the four years displayed on this table, there are minor differences in monthly average temperatures between the No Action Alternative and the Preferred Alternative at this location. At the 10th percentile, the average monthly temperatures are as much as 1.4°C warmer under the Preferred Alternative than under the No Action Alternative. These small temperature differences are potentially meaningful in the context of fish habitat (Section 4.8 and Appendix R).*

4.5.4.3 Lake Mead and Hoover Dam

Water quality modeling provided in the SCOP FEIS showed that Lake Mead temperatures would change by no more than 1ºC (1.8°F) when lake elevations are drawn down from 1,178 feet msl to 1,000 feet msl (Clean Water Coalition 2006). The probability of Lake Mead elevations less than 1,000 feet msl is small (zero to two percent) over the interim period for all alternatives, with the exception of the Water Supply Alternative, which has a maximum of 12 percent probability in 2026 (Section 4.3). Based on these results, the potential impact of the alternatives on Lake Mead water temperature is considered negligible.

4.5.5 Sediment and Dissolved Oxygen

The maximum headcutting of sediment deltas occurs when a deeply drawn down reservoir receives very high inflows, similar to that observed in Lake Powell in 2005. This condition is very dependent on the reservoir elevation and spring inflow volume. Compared to the No Action Alternative, the projected additional reservoir drawdown under the Water Supply Alternative could result in additional headcutting of sediment deltas and accompanying water quality impacts. The Reservoir Storage Alternative could result in a decrease in sediment delta headcutting if the projected reservoir elevations remain higher than under the No Action Alternative. Since the projected reservoir drawdown under the Basin States and Conservation Before Shortage Alternatives, and the Preferred Alternative are similar, headcutting of sediment deltas would likely be similar.

Quantified water quality impacts from reservoir sediment delta headcutting are not currently available, nor is it possible to quantitatively distinguish the impact of sediment headcutting among the alternatives. However, recent history shows that high inflows causing sediment delta headcutting likely increases phosphorus release and biological oxygen demand. Large spring inflows then can bring this plume of low dissolved oxygen laden water near the powerplant intakes and result in low dissolved oxygen carrying releases. There may be short term impacts to food base and trout resources between Glen Canyon Dam and Lees Ferry due to these occurrences. Recurrences of low dissolved oxygen such as the one that occurred in 2005 downstream of Glen Canyon Dam may result from reservoir drawdown cycles under any of the alternatives. This condition mostly affects the reach between Glen Canyon Dam and Lee’s Ferry since the Colorado River reaerates itself after passing through the rapids downstream of Lees Ferry.

With respect to riverine sediment transport in the Glen Canyon Dam to Lake Mead reach, annual releases lower than 8.23 maf associated with the action alternatives would transport less sediment through Grand Canyon into Lake Mead than under the No Action Alternative. However, some of this effect could be offset by a slightly higher proportion of equalization or balancing releases in these alternatives (Figure 4.3-13).

To estimate the sediment transport impacts of potentially modifying the annual Glen Canyon Dam releases, the USGS prepared an analysis relating normalized sediment transport from Grand Canyon to these annual releases. Table 4.5-8 shows this relationship, with 8.23 maf release volumes as the basis for normalization.

Table 4.5-8
Relationship of Glen Canyon Dam Annual Release Volumes
to Sediment Transport from Grand Canyon

Release (maf)	Normalized Sediment Transport
6.00	0.26
7.00	0.51
8.00	0.89
8.23	1.00
9.00	1.43
10.00	2.15
11.00	3.03
12.00	4.11
13.00	5.43
14.00	7.01
15.00	8.88
16.00	11.02
17.00	13.53
18.00	16.67
19.00	19.72
20.00	23.40

Annual release values obtained from all the traces of RiverWare™ analyses for all the alternatives were applied to this sediment transport relationship for the years 2008, 2016, 2026, and 2060. Relative differences among the alternatives were calculated by comparing the action alternatives to the No Action Alternative at the 10th, 50th, and 90th percentiles of sediment transport. These normalized comparisons are shown in Table 4.5-9 for the years 2008, 2016, 2026, and 2060, respectively.

The data provided in Table 4.5-9 show that in the near term, nearly the same amount of sediment is transported under the alternatives, but that in 2016 and 2026, under the Basin States and Conservation Before Shortage Alternatives, and the Preferred Alternative, potentially more sediment can be transported as water is moved from Lake Powell to Lake Mead under the coordinated operations where balancing results in increased releases from Lake Powell. Under the Water Supply Alternative even more sediment can be transported as a greater amount of water is moved to Lake Mead between 2016 and 2026. Under the Reservoir Storage Alternative, the amount of sediment transport is reduced as releases and water deliveries are reduced to keep Lake Mead, and subsequently Lake Powell, at higher pool elevations.

Table 4.5-9
Sediment Transport (normalized to 8.23 maf annual release volume)
Comparison of Action Alternatives to No Action Alternative
90th, 50th, and 10th Percentile Values

	90th Percentile		50th Percentile		10th Percentile	
	Annual Release (maf)	Sediment Transport	Annual Release (maf)	Sediment Transport	Annual Release (maf)	Sediment Transport
Year 2008						
No Action	10.98	3.02	8.23	1	8.23	1
Basin States	11.22	3.26	8.23	1	8.23	1
Conservation Before Shortage	11.22	3.26	8.23	1	8.23	1
Water Supply	10.98	3.02	8.23	1	8.23	1
Reservoir Storage	10.98	3.02	8.23	1	7.80	0.83
Preferred Alternative	11.22	3.26	8.23	1	8.23	1
Year 2016						
No Action	12.91	5.35	8.23	1	8.23	1
Basin States	13.00	5.43	9.00	1.43	8.23	1
Conservation Before Shortage	13.05	5.55	9.00	1.43	8.23	1
Water Supply	12.67	5.01	9.50	1.78	8.23	1
Reservoir Storage	13.23	5.82	8.23	1	7.80	0.83
Preferred Alternative	13.13	5.67	9.00	1.43	8.23	1
Year 2026						
No Action	12.78	5.16	8.23	1	8.23	1
Basin States	12.69	5.03	9.00	1.43	8.23	1
Conservation Before Shortage	12.78	5.16	9.00	1.43	8.23	1
Water Supply	12.73	5.09	9.50	1.78	8.23	1
Reservoir Storage	12.78	5.16	8.23	1	7.89	0.87
Preferred Alternative	12.96	5.42	9.00	1.43	8.23	1
Year 2060						
No Action	12.48	4.75	8.23	1	8.23	1
Basin States	12.48	4.75	8.23	1	8.23	1
Conservation Before Shortage	12.48	4.75	8.23	1	8.23	1
Water Supply	12.48	4.75	8.23	1	8.23	1
Reservoir Storage	12.48	4.75	8.23	1	8.23	1
Preferred Alternative	12.48	4.75	8.23	1	8.23	1

Modeling completed for the SCOP FEIS determined that there would be no adverse effects on dissolved oxygen as a result of the SCOP project or due to drawdown of Lake Mead from elevation 1,178 feet msl to 1,000 feet msl. The probability of Lake Mead elevations less than 1,000 feet msl is small (zero to two percent) over the interim period for all alternatives, with the exception of the Water Supply Alternative, which has a maximum of 12 percent probability in 2026 (Section 4.3). Based on these results, potential effects of the alternatives on dissolved oxygen in Lake Mead are considered negligible. Futhermore, monitoring of dissolved oxygen levels in Lake Mead will be conducted as part of the SCOP BBAMP (Clean Water Coalition 2006).

4.5.6 Nutrients and Algae

Most of the 1.0 mg/L of total phosphorus concentration entering Lake Powell from the major tributaries is bound to the sediment and primarily settles out with the sediment (Section 3.5). Bioavailable phosphorus from the major inflows is generally only 0.007 to 0.009 mg/L and phosphorus concentrations released from Glen Canyon Dam and Hoover Dam generally range from only 0.004 to 0.008 mg/L with occasional spikes to near 0.012 mg/L. Sediment delta headcutting releases phosphorus. This release can significantly boost primary productivity in reservoir inflow areas. A decrease in reservoir elevation could result in additional headcutting in the sediment deltas; however, data is not available to project the amount of headcutting and phosphorous release for different reservoir elevations.

When Lake Powell is full, Glen Canyon Dam release temperatures and inflow temperatures into Lake Mead are cool, and the plume of water entering Lake Mead drops to depths below which algae can grow. Therefore, much of the inflowing phosphorus that is not settled out with the sediment in Lake Mead travels to Hoover Dam. However, when Lake Powell elevations are low enough to produce warm Glen Canyon Dam releases and inflow temperatures into Lake Mead, the inflow plume into Lake Mead will remain nearer the surface where light would increase productivity. The algae thus produced would settle out, trap more phosphorus in the sediment in Lake Mead, and reduce the phosphorus transport down-reservoir into Boulder Basin. Due to the complexity of the system, the direct impact due to the different alternatives can not be projected.

Modeling results provided in the SCOP FEIS showed that there would be no adverse effects on phosphorous concentrations, other nutrients or algae as a result of the SCOP or from Lake Mead being drawn down from elevation 1,178 feet msl to 1,000 feet msl (Clean Water Coalition 2006). The probability of Lake Mead elevations less than 1,000 feet msl is small (zero to two percent) over the interim period for all alternatives, with the exception of the Water Supply Alternative, which has a maximum of 12 percent probability in 2026 (Section 4.3). Based on these results, the concentrations of phosphorus in Boulder Basin and Las Vegas Bay should remain within the Nevada TMDL under all alternatives. Furthermore, the SCOP BBAMP will monitor nutrients and chlorophyll levels in Lake Mead and manage nutrient loadings if water quality objectives are not met (Clean Water Coalition 2006).

4.5.7 Metals

Modeling results provided in the SCOP FEIS for Lake Mead show that the lake's ability to dilute contaminant and nutrient loadings from Las Vegas Valley wastewater treatment plants is not significantly diminished when Lake Mead elevation is 1,000 feet msl in comparison to 1,178 feet msl (Clean Water Coalition 2006). The probability of Lake Mead elevations less than 1,000 feet msl is small (zero to two percent) over the interim period for all alternatives, with the exception of the Water Supply Alternative, which has a maximum of 12 percent probability in 2026 (Section 4.3). Therefore, it is anticipated that drawdown of Lake Mead under any of the alternatives will not increase metals concentrations as a result of reduced dilution.

4.5.8 Perchlorate

Since 1999, perchlorate containment and reduction strategies have resulted in the decline of detectable concentrations 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. Perchlorate concentrations are ranging from non-detectable levels to six parts per billion (ppb), indicating a slow and steady decline (Blasius 2006, personal communication). Modeling provided for the SCOP FEIS included a perchlorate analysis and showed that the dilution capacity of Lake Mead did not significantly change when Lake Mead elevations are drawn down from 1,178 feet msl to 1,000 feet msl. The probability of Lake Mead elevations less than 1,000 feet msl is small (zero to two percent) over the interim period for all alternatives, with the exception of the Water Supply Alternative, which has a maximum of 12 percent probability in 2026 (Section 4.3). Therefore, Lake Mead drawdown under any of the action alternatives is not expected to affect perchlorate concentrations.

4.5.9 Summary

The following conclusions were drawn from the analyses of potential effects on water quality constituents of concern.

4.5.9.1 Salinity

The future average annual salinity levels under the action alternatives are not expected to exceed the salinity numeric criteria established by the Colorado River Basin Salinity Control Forum for different locations on the lower Colorado River.

4.5.9.2 Temperature

The temperature range for Glen Canyon Dam releases under the Water Supply Alternative is warmer due to the corresponding lower Lake Powell reservoir elevations at the 10^{th} and 50^{th} percentiles. The Reservoir Storage Alternative results in cooler temperatures for Glen Canyon Dam release at the 10^{th} and 50^{th} percentiles of reservoir elevations for some years. The temperature of Glen Canyon Dam releases under the Basin States Alternative, Conservation Before Shortage Alternative, and the Preferred Alternative are similar to those under the No Action Alternative.

For Lake Mead, modeling performed for the SCOP FEIS showed that lake temperatures would change by no more than 1ºC (1.8º F) when Lake Mead elevations are drawn down from 1,178 feet msl to 1,000 feet msl (Clean Water Coalition 2006). The probability of Lake Mead being drawn down to below elevation 1,000 feet msl is low for all alternatives. Therefore, potential effects of the alternatives on Lake Mead water temperatures are considered to be negligible.

4.5.9.3 Other Water Quality Parameters

The following findings relate to other water quality parameters assessed:

- ♦ for Lake Powell, quantified water quality impacts from reservoir sediment delta headcutting are not currently available;
- ♦ for Lake Mead, the projected elevations and corresponding changes in dilution capacity are not expected to result in any increase in metals concentrations of concern; and
- ♦ for Lake Mead, it is not anticipated that any of the action alternatives would result in a significantly increased concentration of perchlorate.

For Lake Mead, hydrologic and water quality modeling provided in the SCOP FEIS determined that drawing down Lake Mead elevations to 1,000 feet msl would not have a significant effect on water quality in Lake Mead, Hoover Dam releases, and the SNWA water pumped from Lake Mead. The probability of Lake Mead being drawn down below elevation 1,000 feet msl is small for all alternatives with the exception of the Water Supply Alternative. Therefore, potential effects of the alternatives on water quality parameters in Lake Mead are considered negligible.

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4.6 Air Quality

This section describes the methods of analysis and potential effects on air quality at Lake Powell and Lake Mead, focusing on particulate matter. Potential effects on Glen Canyon Dam to Lake Mead reach from particulate emissions at the Lake Mead delta are also considered.

4.6.1 Methodology

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 will vary depending upon sediment characteristics and other factors such as saturation, sediment disturbance, wind speeds, and topography. The method for assessing potential fugitive emissions from exposed shoreline sediments at Lake Powell and Lake Mead includes the following assumptions.

- the area of exposed shoreline for Lake Powell was developed using an average shoreline slope of 45 degrees. The area of exposed shoreline for Lake Mead was developed from bathymetry data; and

- incremental changes to Lake Powell and Lake Mead elevations were developed corresponding to the years 2008 through 2060 from the CRSS modeling output. The 10^{th} percentile elevations at the end of March for Lake Powell and at the end of July for Lake Mead were selected as worst-case assumptions that have a reasonable probability of occurring. These elevations were then correlated to the reservoir surface areas (acres) and compared to the maximum elevations for Lake Powell (3,700 feet msl) and Lake Mead (1,221 feet msl) to determine the acres of exposed shoreline.

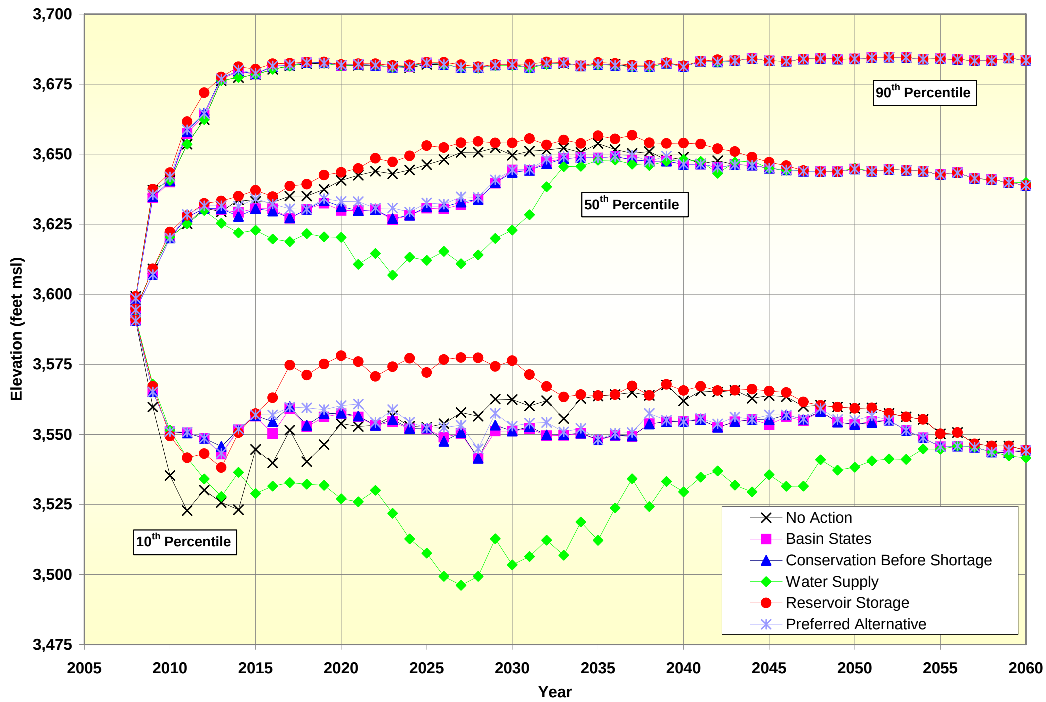
4.6.2 Lake Powell and Glen Canyon Dam

4.6.2.1 No Action Alternative

The lowest Lake Powell elevation occurs in March (Figure 4.6-1). For a comparative evaluation, the years 2008, 2016, 2025, 2040, 2050, and 2060 were examined under the No Action Alternative. The low Lake Powell elevation at the 10^{th} percentile was projected for the year 2025 with about 17,000 acres of exposed shoreline. For a comparative discussion, the action alternatives are compared to the No Action Alternative for the year 2025.

The potential for fugitive emissions is limited by the extent of the area containing fine sediment having the potential to generate dust. Areas of fine sediments at Lake Powell comprise about three percent of the 1,960 miles of shoreline (NPS 2002). The remainder of Lake Powell shoreline consists of Navajo Sandstone and other Glen Canyon Group rock formations. These rock formations are not conducive to creating significant amounts of dust.

Figure 4.6-1
Lake Powell End-of-March Elevations
Comparison of Action Alternatives to No Action Alternative
90th, 50th, and 10th Percentile Values



4.6.2.2 Basin States Alternative

At the 10th percentile, Lake Powell elevation is projected to be 3,552 feet msl in the year 2025 under the Basin States Alternative, resulting in approximately 17,000 acres of exposed shoreline. This would result in no change in exposed shoreline compared to the No Action Alternative (Table 4.6-1). With no change in shoreline acreage, there would be no increased potential to exceed the federal PSD Class II threshold or state and national Ambient Air Quality Standards (AAQS) when compared to the No Action Alternative.

Table 4.6-1
Lake Powell End-of-March 10th Percentile Elevation and Exposed Shoreline (rounded to nearest whole number)

Year	No Action	Basin States	Conservation Before Shortage	Water Supply	Reservoir Storage	Preferred Alternative
2008						
Surface Elevation (feet msl)	3,591	3,591	3,591	3,591	3,591	3,591
Exposed Shoreline Area (acres x 1,000)	12	12	12	12	12	12
Percent Difference Compared to No Action Alternative	0	0	0	(1)	(0)	0
2016						
Surface Elevation (feet msl)	3,540	3,550	3,555	3,532	3,563	3,557
Exposed Shoreline Area (acres x 1,000)	18	17	16	19	15	16
Percent Difference Compared to No Action Alternative[1]	0	(7)	(9)	5	(15)	(11)
2025						
Surface Elevation (feet msl)	3,552	3,552	3,552	3,508	3,572	3,552
Exposed Shoreline Area (acres x 1,000)	17	17	17	22	14	17
Percent Difference Compared to No Action Alternative	0	0	0	30	(13)	0
2040						
Surface Elevation (feet msl)	3,562	3,555	3,555	3,529	3,566	3,555
Exposed Shoreline Area (acres x 1,000)	16	16	16	19	15	16
Percent Difference Compared to No Action Alternative	0	5	5	24	(3)	5
2050						
Surface Elevation (feet msl)	3,559	3,554	3,554	3,538	3,559	3,555
Exposed Shoreline Area (acres x 1,000)	16	17	17	18	16	16
Percent Difference Compared to No Action Alternative	0	4	4	15	0	3
2060						
Surface Elevation (feet msl)	3,544	3,544	3,544	3,542	3,544	3,544
Exposed Shoreline Area (acres x 1,000)	18	18	18	18	18	18
Percent Difference Compared to No Action Alternative	0	0	0	2	0	0

1 Parenthesis indicates a reduction in exposed shoreline as compared to the No Action Alternative.

4.6.2.3 Conservation Before Shortage Alternative

At the 10th percentile, Lake Powell elevation is projected to be 3,552 feet msl in the year 2025 under the Conservation Before Shortage Alternative. Drawdown of Lake Powell to this elevation could result in approximately 17,000 acres of exposed shoreline. This would result in no change in the exposed shoreline compared to the No Action Alternative (Table 4.6-1).

With no change in shoreline acreage, there would be no increased potential to exceed the PSD Class II threshold or the state or national AAQS when compared to the No Action Alternative.

4.6.2.4 Water Supply Alternative

At the 10th percentile, Lake Powell elevation is projected to be 3,508 feet msl in the year 2025 under the Water Supply Alternative, resulting in approximately 30,000 acres of exposed shoreline. This would result in a 30 percent increase in exposed shoreline compared to the No Action Alternative (Table 4.6-1).

This increase would potentially have a negative effect on air quality compared to the No Action Alternative. As sediment comprises about three percent of the 1,960 miles of shoreline, the increase in acreage susceptible to wind erosion would not result in exceedance of the PSD Class II threshold or the state or national AAQS.

4.6.2.5 Reservoir Storage Alternative

At the 10th percentile, Lake Powell elevation is projected to be 3,572 feet msl in the year 2025 under the Reservoir Storage Alternative. Drawdown of Lake Powell to this elevation would result in a decrease of approximately 14,000 acres of exposed shoreline. For the Reservoir Storage Alternative, this would result in a decrease of about 14 percent in exposed shoreline compared to the No Action Alternative (Table 4.6-1).

The Reservoir Storage Alternative would result in having the highest potential to reduce dust emissions and increased beneficial impact to air quality. Due to a decrease in exposed shoreline acreage, the potential to exceed the PSD Class II threshold or the state or national AAQS would also be decreased.

4.6.2.6 Preferred Alternative

At the 10th percentile, Lake Powell elevation is projected to be 3,552 feet msl in the year 2025 under the Preferred Alternative, resulting in approximately 17,000 acres of exposed shoreline. This would result in no change in the exposed shoreline compared to the No Action Alternative (Table 4.6-1).

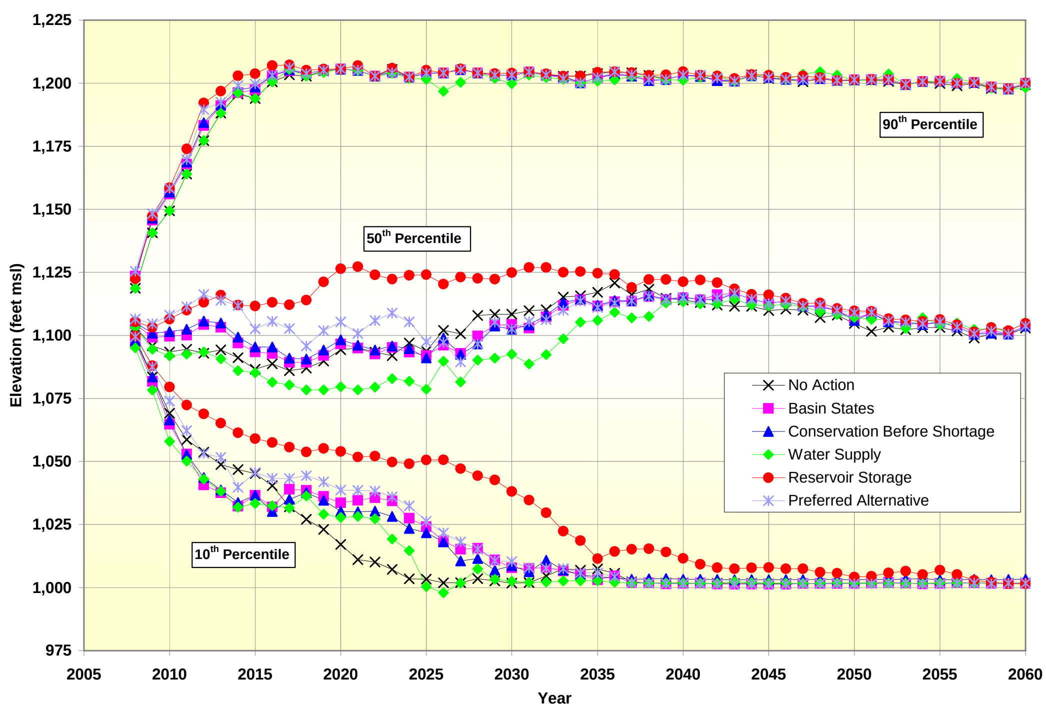
With no change in shoreline acreage, there would be no increased potential to exceed the PSD Class II threshold or the state or national AAQS when compared to the No Action Alternative. The potential to impact air quality would also be similar to that projected for the Basin States and the Conservation Before Shortage alternative.

4.6.3 Glen Canyon Dam to Lake Mead, Lake Mead and Hoover Dam

4.6.3.1 No Action Alternative

The lowest Lake Mead elevation occurs in July (Figure 4.6-2). Under the No Action Alternative, Lake Mead elevation would be drawndown to 1,003 feet msl for the year 2025, resulting in approximately 89,000 acres of exposed shoreline (Table 4.6-2). A comparative discussion of the action alternatives and the No Action Alternative for the year 2025 follows.

Figure 4.6-2
Lake Mead End-of-July Elevations
Comparison of Action Alternatives to No Action Alternative
90th, 50th, and 10th Percentile Values



4.6.3.2 Basin States Alternative

At the 10th percentile, Lake Mead elevation is projected to be 1,024 feet msl in the year 2025 under the Basin States Alternative, resulting in approximately 82,000 acres of exposed shoreline. For the Basin States Alternative, this would result in a decrease of about eight percent in exposed shoreline when compared to the No Action Alternative (Table 4.6-2). This decrease in acreage would be directly proportional to the area susceptible to wind erosion and fugitive dust emission. With a decrease in exposed shoreline acreage, the potential to exceed the PSD Class I or II thresholds or the state or national AAQS would also decrease. The eight percent decrease would result in a beneficial effect compared to the No Action Alternative.

Table 4.6-2
Lake Mead End-of-July 10th Percentile Elevation and Exposed Shoreline (Rounded to Nearest Whole Number)

Year	No Action	Basin States	Conservation Before Shortage	Water Supply	Reservoir Storage	Preferred Alternative
2008						
Surface Elevation (feet msl)	1,099	1,097	1,098	1,095	1,100	1,099
Exposed Shoreline Area (acres x 1,000)	57	58	58	58	57	57
Percent Difference Compared to No Action Alternative[1]	0	1	0	2	(0)	(0)
2016						
Surface Elevation (feet msl)	1,040	1,032	1,030	1,032	1,058	1,043
Exposed Shoreline Area (acres x 1,000)	78	80	81	80	71	77
Percent Difference Compared to No Action Alternative	0	3	3	3	(9)	(2)
2025						
Surface Elevation (feet msl)	1,003	1,024	1,022	1,000	1,051	1,026
Exposed Shoreline Area (acres x 1,000)	89	82	83	90	73	82
Percent Difference Compared to No Action Alternative	0	(8)	(8)	1	(18)	(9)
2040						
Surface Elevation (feet msl)	1,002	1,002	1,003	1,002	1,012	1,001
Exposed Shoreline Area (acres x 1,000)	90	90	90	90	87	90
Percent Difference Compared to No Action Alternative	0	0	(0)	(0)	(3)	0
2050						
Surface Elevation (feet msl)	1,002	1,002	1,003	1,002	1,006	1,002
Exposed Shoreline Area (acres x 1,000)	90	90	90	90	89	90
Percent Difference Compared to No Action Alternative	0	0	(0)	0	(1)	0
2060						
Surface Elevation (feet msl)	1,002	1,002	1,003	1,001	1,002	1,002
Exposed Shoreline Area (acres x 1,000)	90	90	89	90	90	90
Percent Difference Compared to No Action Alternative	0	0	(0)	0	0	0

1 Parenthesis indicates a reduction in exposed shoreline compared to the No Action Alternative.

4.6.3.3 Conservation Before Shortage Alternative

At the 10th percentile, Lake Mead elevation is projected to be 1,022 feet msl in the year 2025 under the Conservation Before Shortage Alternative, resulting in approximately 83,000 acres of exposed shoreline. For the Conservation Before Shortage Alternative, this would result in a decrease of about eight percent in exposed shoreline when compared to the No Action Alternative (Table 4.6-2).

The decrease in acreage would be directly proportional to the area susceptible to wind erosion and fugitive dust emissions. With a decrease in exposed shoreline acreage, the potential to exceed the PSD Class I or II thresholds or the state or national AAQS would also decrease. The potential decrease would result in a beneficial impact to the environment compared to the No Action Alternative.

4.6.3.4 Water Supply Alternative

At the 10th percentile, Lake Mead elevation is projected to be 1,000 feet msl in the year 2025 under the Water Supply Alternative, resulting in approximately 90,000 acres of exposed shoreline. For the Water Supply Alternative, this would result in an increase of about one percent in exposed shoreline when compared to the No Action Alternative (Table 4.6-2). The Water Supply Alternative would have potentially the same impact compared to the No Action Alternative.

Changes in shoreline acreage would be directly proportional to the area susceptible to wind erosion and fugitive dust emissions. With a less than one percent change in exposed shoreline acreage, the potential to exceed the PSD Class I or II thresholds or the state or national AAQS would be minimal compared to the No Action Alternative.

4.6.3.5 Reservoir Storage Alternative

At the 10th percentile, Lake Mead elevation is projected to be 1,051 feet msl in the year 2025 under the Reservoir Storage Alternative, resulting in approximately 73,000 acres of exposed shoreline. For the Reservoir Storage Alternative, this would result in a decrease of about 18 percent in exposed shoreline when compared to the No Action Alternative (Table 4.6-2). Compared to the No Action Alternative, the Reservoir Storage Alternative would have the most potential to reduce fugitive emissions and result in beneficial impact to air quality.

The decrease in acreage would be directly proportional to the area susceptible to wind erosion and fugitive dust emissions. With a decrease in exposed shoreline acreage, the potential to exceed the PSD Class I or II thresholds or the state or national AAQS would also be decreased. The decrease would result in a beneficial impact to the environment compared to the No Action Alternative.

4.6.3.6 Preferred Alternative

At the 10th percentile, Lake Mead elevation is projected to be 1,026 feet msl in the year 2025 under the Preferred Alternative, resulting in approximately 82,000 acres of exposed shoreline. For the Preferred Alternative, this would result in a decrease of about nine percent in exposed shoreline when compared to the No Action Alternative (Table 4.6-2).

The decrease in acreage would be directly proportional to the area susceptible to wind erosion and fugitive dust emissions. With a decrease in exposed shoreline acreage, the potential to exceed the PSD Class I or II thresholds or the state or national AAQS would also decrease. The potential decrease would result in a beneficial impact to the environment compared to the No Action Alternative.

4.6.4 Summary

The projected exposed shoreline acreage under the Basin States and Conservation Before Shortage alternatives, and the Preferred Alternative, are similar (i.e., from zero to five percent for the year 2025) to that projected under the No Action Alternative at Lake Powell. In general, the greatest increase in exposed shoreline acreage (i.e., about 30 percent for the year 2025) compared to the No Action Alternative at Lake Powell is projected under the Water Supply Alternative; the greatest reduction (i.e., about 15 percent for the year 2025) is projected under the Reservoir Storage Alternative. This trend can be observed in Figure 4.6-1.

Except for the Reservoir Storage Alternative, all of the action alternatives are projected to have similar or decreased shoreline exposure (i.e., from a less than one percent increase to a nine percent decrease) compared to the No Action Alternative for Lake Mead, and for Glen Canyon Dam to Lake Mead reach (Lake Mead delta). There is a greater potential for reduction in shoreline acreage exposure (i.e., 18 percent for the year 2025) in the Reservoir Storage Alternative and this potential is generally consistent for all years. This trend can be observed in Figure 4.6-2.

As reservoir elevations decrease and more shoreline is exposed, the potential for increased fugitive dust emission increases. However, an increase in fugitive emissions as a result of increased exposed shoreline would be limited at Lake Powell because the increased exposure of acreage would be comprised largely of sandstone, which is not conducive to generating PM10 standard fugitive emissions.

4.7 Visual Resources

This section describes the methods used in the Final EIS for analyzing the potential effects of changing reservoir elevations on visual resources at Lake Powell and Lake Mead, focusing on selected attraction features, calcium carbonate rings, and sediment deltas.

4.7.1 Methodology

To determine how changes in reservoir elevation might affect attraction features, data provided in Table 4.3-9 (Section 4.3) for end-of-September (the month of highest visitation) Lake Powell elevations were used to compare effects of the alternatives on exposure of Cathedral in the Desert. Table 4.3-9 provides percentage of values less than or equal to Lake Powell reservoir elevation of 3,550 feet msl for multiple years. Elevation 3,550 feet msl is significant because Cathedral in the Desert becomes visible at or below that elevation (Section 3.7).

For calcium carbonate rings, reservoir elevations at the 10th percentile were used. Months representative of lowest reservoir elevations were used to provide a worst case analysis, or maximum extent of calcium carbonate rings; March was selected for Lake Powell and July was selected for Lake Mead, using data provided in Section 4.6 (Tables 4.6-1 and 4.6-2, respectively). The height of the calcium carbonate ring was calculated as the distance in feet from full pool elevations of Lake Powell (3,700 feet msl) and Lake Mead (1,221 feet msl) to the lowest lake elevation within the modeling time period.

The method of analysis used for projecting potential effects on calcium carbonate rings in Section 4.6 was utilized to understand relative differences between the action alternatives and the No Action Alternative for sediment deltas. The 10th percentile of reservoir elevations in the months representative of lowest reservoir elevations, March for Lake Powell and July for Lake Mead, for the year 2026 are used in the Final EIS to provide a relative comparison of effects of the action alternatives on sediment deltas to the No Action Alternative.

4.7.2 Lake Powell and Glen Canyon Dam

4.7.2.1 Attraction Features

No Action Alternative. Using the modeling projections described above, there is a five percent probability of exposing the Cathedral in the Desert under the No Action Alternative. The upstream face of Glen Canyon Dam will be slightly more exposed, but this is not considered a measurable visual impact.

Basin States Alternative and Conservation Before Shortage Alternative. Under these two action alternatives, there is a seven percent chance of exposure of Cathedral in the Desert.

Water Supply Alternative. There is a 17 percent chance of exposure of Cathedral in the Desert.

Reservoir Storage Alternative. There is a three percent chance of exposure of Cathedral in the Desert.

Preferred Alternative. There is a seven percent chance of exposure of Cathedral in the Desert.

4.7.2.2 Calcium Carbonate Rings and Sediment Deltas

No Action Alternative. The 10^{th} percentile values for March 2025 indicate a low Lake Powell reservoir elevation of 3,552 feet msl under the No Action Alternative, thus creating a potential calcium carbonate ring of 148 feet in height. Sediment deltas will continue to build up over time and be visible under the No Action Alternative. Ferrari's (2006) longitudinal profile indicates that the sediment delta is visible for at least 15 miles upstream of Hite. At 10^{th} percentile projections, the delta may be visible from as far away as 25 miles, essentially from Hite to Gypsum Canyon.

Basin States Alternative and Conservation Before Shortage Alternative. The 10^{th} percentile values for March 2025 indicate a low Lake Powell reservoir elevation of 3,552 feet msl under these two action alternatives, thus creating a potential calcium carbonate ring of 148 feet in height, the same as under the No Action Alternative. The sediment deltas would be exposed and visible to the same extent as under the No Action Alternative.

Water Supply Alternative. The 10^{th} percentile values for March 2025 indicate a low Lake Powell reservoir elevation of 3,508 feet msl under the Water Supply Alternative, thus creating a potential calcium carbonate ring of 192 feet in height. Sediment deltas would be more exposed and visible than under the No Action Alternative.

Reservoir Storage Alternative. The 10^{th} percentile values for March 2025 indicate a low Lake Powell reservoir elevation of 3,572 feet msl under the Reservoir Storage Alternative, thus creating a potential calcium carbonate ring of 128 feet in height. Potential exposure of sediment deltas would be less visible than under the No Action Alternative.

Preferred Alternative. The 10^{th} percentile values for March 2025 indicate a low Lake Powell reservoir elevation of 3,552 feet msl under the Preferred Alternative, thus creating a potential calcium carbonate ring of 148 feet in height, the same as under the No Action Alternative. Sediment deltas would be exposed and visible to the same extent as under the No Action Alternative.

4.7.3 Glen Canyon Dam to Lake Mead

The proposed federal action would have no effects on the visual resources in this reach because daily and hourly flows would generally be similar under all alternatives.

4.7.4 Lake Mead and Hoover Dam

4.7.4.1 Attraction Features

Hoover Dam is a major destination and a national landmark. The proposed federal action would not have any visual effects on this resource.

4.7.4.2 Calcium Carbonate Rings and Sediment Deltas

No Action Alternative. The 10th percentile values for July 2025 indicate a low Lake Mead reservoir elevation of 1,003 feet msl under the No Action Alternative, thus creating a potential calcium carbonate ring of 218 feet in height. Sediment deltas are visible primarily to water-based recreationists, though they can also be viewed by visitors of the Lake Mead NRA (Section 3.7).

Basin States Alternative and Conservation Before Shortage Alternative. The 10th percentile values for July 2025 indicate a low Lake Mead reservoir elevations of 1,024 feet msl for the Basin States Alternative and 1,022 for the Conservation Before Shortage Alternative, thus creating a potential calcium carbonate ring of 197 feet and 199 feet in height, respectively. Sediment deltas would be somewhat less visible than under the No Action Alternative.

Water Supply Alternative. The 10th percentile values for July 2025 indicate a low Lake Mead reservoir elevation of 1,000 feet msl under the Water Supply Alternative, thus creating a potential calcium carbonate ring of 221 feet in height. Sediment deltas would be only slightly more exposed and therefore slightly more visible than under the No Action Alternative.

Reservoir Storage Alternative. The 10th percentile values for July 2025 indicate a low Lake Mead reservoir elevation of 1,051 feet msl under the Reservoir Storage Alternative, thus creating a potential calcium carbonate ring of 170 feet in height. Sediment deltas would be less exposed and therefore less visible than under the No Action Alternative.

Preferred Alternative. The 10th percentile values for July 2025 indicate a low Lake Mead reservoir elevation of 1,026 feet msl under the Preferred Alternative, thus creating a potential calcium carbonate ring of 195 feet in height. Sediment deltas would be somewhat less exposed and therefore less visible than under the No Action Alternative.

4.7.5 Summary

The probability of exposing Cathedral in the Desert ranged from three to 17 percent under the alternatives. The Water Supply Alternative would offer the greatest chance that visitors could see Cathedral in the Desert, while the Reservoir Storage Alternative offers the least chance. Most would agree that Cathedral in the Desert was one of the most spectacular geological features in Glen Canyon before inundation; seeing this feature would be considered a positive visual impact. There would be no visual effects on attraction features at Lake Mead.

At Lake Powell, the maximum height of calcium carbonate rings ranged from 192 feet under the Water Supply Alternative to 148 feet under the Basin States and Conservation Before Shortage alternatives, the Preferred Alternative, and the No Action Alternative, and to 128 feet under the Reservoir Storage Alternative. At Lake Mead, the maximum height of calcium carbonate rings ranged from 170 feet under the Reservoir Storage Alternative to 221 feet under the Water Supply Alternative, which is somewhat similar to the 218 foot height under the No Action Alternative. The calcium carbonate ring height under the Basin States and Conservation Before Storage alternatives, and the Preferred Alternative was around 197 feet. For both reservoirs, the presence of the calcium carbonate ring produces an effect regardless of its height. Therefore, while there are numeric differences in the projected height of the rings, the overall difference in visual impact among the alternatives is not considered significant.

At the inflow areas to both Lake Powell and Lake Mead, sediment deltas will continue to build up over time and be visible under all alternatives. Their relative exposure and visibility are directly related to reservoir elevations. The differences among all alternatives are negligible for both Lake Powell and Lake Mead.

4.8 Biological Resources

This section describes the environmental consequences related to biological resources associated with implementation of the proposed federal action, and describes the methods used to determine these effects. This section also provides descriptions of two ongoing environmental protection programs within the study area.

4.8.1 Related Environmental Programs

Reclamation is committed to compliance with environmental statutes such as the ESA and the Grand Canyon Protection Act. The following are ongoing collaborative programs intended to meet environmental compliance requirements.

4.8.1.1 Glen Canyon Dam Adaptive Management Program

Impacts to biological resources downstream of Glen Canyon Dam are considered in the Glen Canyon Dam Adaptive Management Program, which was established to monitor the effects of Glen Canyon Dam operations and other management actions on the downstream environment. This program makes recommendations to the Secretary regarding ways to fulfill the resource protection requirements of the Grand Canyon Protection Act while complying with all applicable federal laws. This program will continue to analyze the effects of varied conditions on biological resources downstream of Lake Powell.

4.8.1.2 Lower Colorado River Multi-Species Conservation Program

For a portion of the study area, Reclamation is the implementing agency for the LCR MSCP. This program mitigates potential flow-related and non-flow related impacts to biological resources along the lower Colorado River. These impacts could result from various federal and non-federal actions over the next 50 years along the lower Colorado River from Lake Mead to the SIB. This habitat-based program is being implemented to mitigate impacts to special status species, although benefits of the LCR MSCP will accrue to all species that utilize those habitats. This program covers potential impacts to the same types of habitats that may be affected by flow-related impacts of the action alternatives. For NEPA purposes, the No Action Alternative is used to represent baseline conditions. Reclamation has reviewed the effects of the Preferred Alternative in this Final EIS and has determined that all potential effects on listed species and their habitats along the Colorado River from the full pool elevation of Lake Mead to the SIB are covered by the LCR MSCP. The LCR MSCP BO addresses the effects of covered actions on reduction of Lake Mead reservoir elevations to 950 feet msl, and on flow reductions of up to 0.845 maf from Hoover Dam to Davis Dam, 0.860 maf from Davis Dam to Parker Dam, and 1.574 maf from Parker Dam to Imperial Dam. The LCR MSCP identified and it is mitigating impacts on LCR MSCP covered species and their habitats. Based on the flow reductions described above, these impacts include the potential loss of up to:

- 2,008 acres of cottonwood-willow habitats;
- 133 acres of marsh habitat; and

- 399 acres of backwater habitat.

To address these impacts, the LCR MSCP would:

- restore 5,940 acres of cottonwood-willow habitat;
- restore 512 acres of marsh habitat;
- restore 360 acres of backwater habitat;
- stock 660,000 razorback sucker over the term of the LCR MSCP; and
- stock 620,000 bonytail over the term of the LCR MSCP.

In addition, these habitats would be actively managed to provide habitat values greater than those of the impacted habitats. The quality and in most cases the quantity of restored habitat will be greater than the impacted habitats. Restoration and management of these habitats for LCR MSCP covered species would provide benefit to all flora and fauna that utilize cottonwood-willow, marsh, and backwater habitats along the lower Colorado River.

LCR MSCP flow-related covered activities include flow reductions due to potential implementation of future shortages in the Lower Basin. Reclamation is committed to enacting the conservation measures of the LCR MSCP and these measures will effectively offset any potential minor impacts identified in this Final EIS to cottonwood-willow, marsh, and backwater habitats from Lake Mead to the SIB.

4.8.2 Methodology

Two types of modeling results were used to perform the biological analysis, as follows:

- hydrologic modeling (CRSS) – reservoir elevations, dam releases, river flows; and
- water quality modeling (CE-QUAL-W2 and GEMSS) – water temperatures.

This biological analysis evaluates the relative difference between the action alternatives and the No Action Alternative. The level of available information varies with the study reaches; therefore, the methodology is adjusted according to the availability of information for a particular reach or group of reaches.

4.8.2.1 Assumptions

Desert scrub plant communities would not be affected by lowered reservoir elevations, river stage, or groundwater levels. Cottonwood-willow and marsh vegetation types could be adversely affected by lowered reservoir elevations, river stage, or groundwater levels and may be lost. Saltcedar and mesquite communities would not be adversely affected by lowered groundwater levels. For example, it has been reported that declines in groundwater levels of approximately 3.6 feet caused 92 to 100 percent of cottonwoods and willows to die, while only zero to 13 percent of saltcedar died at the sampling sites along the Bill Williams River (Shafroth et al. 2000).

Davis Dam and Parker Dam will continue to be operated to meet target reservoir elevations and these operations will not vary between alternatives, thus the proposed federal action will not impact riparian and marsh vegetation or wildlife habitats supported by these reservoirs.

The biological analyses are dependent upon the data inputs, modeling assumptions and validity of the CE-QUAL-W2 and GEMSS models for water quality. The historic data and water temperature models represent limited combinations of weather patterns, hydrology, discharge patterns, and reservoir elevations. The upper and lower temperature bounds from this analysis are the best estimates of probable discharge temperature ranges at the indicated reservoir elevations. Additional discussion and data on water temperature is provided in Section 4.5 and in Appendix P.

Inflow temperatures to Lake Mead often do not warm to equilibrium temperatures during much of the year. This is due to upstream cold releases from Lake Powell. The cool inflows restrict the depth of surface water warming and contribute to cooler discharge temperatures from Hoover Dam. If Lake Powell releases were significantly warmer, then inflow temperatures to Lake Mead could reach equilibrium and discharge temperatures would be warmer.

4.8.2.2 Vegetation Assessment Methodology

Lake Powell and Lake Mead. Reservoir elevations under the action alternatives were compared to the No Action Alternative to determine whether shoreline vegetation is more or less likely to establish and/or be inundated.

Glen Canyon Dam to NIB. Projections of average monthly releases from Glen Canyon Dam, Hoover Dam, Davis Dam, and Parker Dam under each action alternative were compared to the No Action Alternative (Figures P-BCR-6 through P-BCR-54; Figures and Tables identified with the letter P throughout this section are located in Appendix P of this Final EIS). The differences between the alternatives, primarily at the 10th percentile, which has the most potential to adversely affect vegetation, were used as an indicator of potential low-flow conditions. To estimate the significance of potential impacts, the modeled releases were analyzed to determine if they would fall inside or outside the annual ranges that have historically occurred in the Colorado River (Section 3.3). Both Scott et al. (1999) and Shafroth et al. (2000) indicated that phreatophytes may develop root systems according to the hydrologic regime under which these plants have developed. Flow variations of several thousand cfs within one month and between months are considered within the range of normal conditions.

In addition to average monthly flows, annual median releases were evaluated to identify potential changes in groundwater along the Colorado River floodplain (Section 4.3, Figures 4.3-32 and 4.3-37). Changes to groundwater levels along the Colorado River may influence riparian and marsh vegetation.

Vegetation impacts from changes in river flow and groundwater levels were assumed to be restricted to those plant communities that consist of obligate phreatophytes (reliant on alluvial groundwater) and/or marsh communities. Based on the relationships used in Appendix K of the LCR MSCP BA (Reclamation 2004c), declines in groundwater levels under the action alternatives could be between 0.25 and 0.5 foot. These reductions would not impact saltcedar and mesquite land cover types because these species are facultative phreatophytes (not solely reliant on alluvial groundwater) and are more tolerant to reductions in surface water and groundwater levels than cottonwood-willow or marsh land cover types.

NIB to SIB. Potential flow changes downstream of the NIB as a result of implementation of the proposed federal action would primarily be the result of potential changes in excess flows (flood flows) arriving at the NIB. The differences in probability of these excess flows under each of the alternatives could potentially affect vegetation between the NIB and the SIB. Probabilities of these excess flows passing downstream of Morelos Diversion Dam under the action alternatives were compared to the No Action Alternative to analyze potential vegetation impacts.

4.8.2.3 Wildlife Assessment Methodology

Terrestrial wildlife was assumed to be affected only where vegetation showed substantial changes from the No Action Alternative.

Analyses of river sport fishery and aquatic food base impacts were based on release temperature modeling, surface water temperature data for Lake Powell, and review of the temperature conclusions in the SCOP FEIS (Clean Water Coalition 2006) for Lake Mead. Since sport fishery is primarily of interest to anglers, effects on this resource are discussed in Section 4.12.

4.8.2.4 Special Status Species Assessment Methodology

Lake Powell and Lake Mead. Analysis of impacts to terrestrial special status species at these two reservoirs were based primarily on the vegetation impact assessment. Potential impacts to special status fish were assessed by comparing reservoir elevations under each action alternative to those under the No Action Alternative. The potential monthly average release temperatures from Lake Powell were also used to analyze potential impacts to special status fish between Glen Canyon Dam and Lake Mead. Previous impact analysis for Lake Mead had used elevation 1,160 feet msl as a threshold for potential impact to razorback sucker spawning areas in Lake Mead. However, recent monitoring has shown that the two subpopulations of razorback sucker in Lake Mead would change their spawning locations in response to lower reservoir elevations (Albrecht and Holden 2006). Lake Mead elevation is currently below 1,160 feet msl. The elevation range of 1,120 feet msl to 1,150 feet msl was used for comparison purposes in this analysis.

Glen Canyon Dam to NIB. Analysis of impacts to terrestrial special status species along the Colorado River were based primarily on the vegetation impact assessment. Impacts to special status fish were based on comparing the modeled average monthly temperatures at Lees Ferry, Little Colorado River, and Diamond Creek to the life history temperature tolerances. There is a wide range of possible downstream temperatures when releases from Lake Powell coincide with lower Lake Powell elevation (Section 1.5; Figures P-BCR-56 through P-BCR-67). In order to provide a more meaningful comparison, the average monthly temperatures were used as the basis for evaluating impacts to special status fish (Tables P-BCR-1 through P-BCR-3). Special status fish impacts were also based on comparing the monthly Lake Mead elevations and monthly releases from Davis Dam and Parker Dam, for which water temperature data were not available. Changes in dam releases that would fall outside the range of flows that typically occur were deemed to cause impacts. Changes in release temperatures from Glen Canyon Dam under the No Action Alternative were used to determine whether impacts to the aquatic food base could in turn impact the special status fish in the Grand Canyon. This analysis used larval chironomids, larval simuliids, *Gammarus lacustris*, and *Cladophora glomerata* as indicator organisms. If a particular alternative would substantially affect non-native sport fish (Section 4.12), this was included in the special status fish assessment.

NIB to SIB. Special status fish species do not exist in this river reach so the analysis was limited to terrestrial special status species. Flows in this reach of the Colorado River are sporadic, with the river channel in the downstream portion of the reach being frequently dry.

4.8.3 Effects on Vegetation and Wildlife

This section discusses the potential impacts to vegetation and wildlife that may result from implementation of the proposed federal action.

4.8.3.1 Lake Powell and Lake Mead

No Action Alternative. Under the No Action Alternative, fluctuation of these reservoirs will continue to inhibit plant growth around the reservoirs over the long term. Lake Powell elevations trend upward at the 50th and 90th percentiles throughout the modeling period. At the 10th percentile, Lake Powell elevations trend temporarily downward (2010 through 2019 and 2041 through 2060), and temporarily upward (2027 through 2041). At the end of the interim period in 2026, Lake Powell elevation is virtually unchanged from current elevations. Figures P-WQA-6, P-BCR-1, and P-BCR-2 provide Lake Powell end-of-March, July, and September elevations, respectively.

Lake Mead elevations exhibit a pronounced downward trend at the 10th percentile. At the 50th percentile, the trend is generally unchanged at the end of the modeling period, though periodic upward and downward trends occur in both the interim and long term. Figures P-BCR-4, P-BCR-6, and P-BCR-7 provide Lake Mead end-of-month elevations for March, July, and September, respectively. To the extent that Lake Mead elevations may be lowered, these lower lake elevations may have effects on biological resources, as described in the following paragraphs.

The sediment deltas in both reservoirs are expected to continue to be colonized by weeds and saltcedar. Lake Mead sediment deltas and the downstream portion of the Grand Canyon have had riparian vegetation become established and persist over long periods of time, until inundated by rising reservoir elevations. The type of vegetation that becomes established in these delta areas is dependent on two factors. The first factor is timing. If the sediment becomes exposed during seed-fall season for cottonwood or willow, then those species are likely to become established. If the sediment becomes exposed during the fall months, then saltcedar is likely to be established and become the dominant vegetation.

A second factor that may influence the type of plant community that may become established in the delta areas is the depth to groundwater or river stage relative to these exposed sediments. As the reservoir elevation declines and the sediment becomes exposed, the level of the river as it downcuts through the newly exposed sediment delta helps determine whether cottonwoods or willows can survive, even if they become established. If the river level drops too far below the root zone of cottonwoods and willows, plant mortality would begin to occur, thus, opening gaps for saltcedar and other species to become established.

Wildlife that utilizes these reservoirs and their shorelines are affected by the fluctuating nature of these habitats to some extent. Reservoir elevation fluctuation would continue into the future, which would continue to alter habitat along the shoreline and below full pool elevation as has occurred in the past.

Quagga mussels have been detected in Lake Mead and in downstream reservoirs, and a small number of zebra and/or quagga mussel larvae were detected in Lake Powell in July 2007 (Section 3.8). Under the No Action Alternative, the potential remains for these mussels to establish in Lake Powell and continue to be present in Lake Mead and in downstream reservoirs. The adoption of guidelines for shortage and coordinated reservoir operations does not affect the potential for colonization in Lake Powell and continued presence in Lake Mead, Lake Mohave and Lake Havasu, or connected waterways. Precautionary measures of cleaning boats entering and leaving these reservoirs will continue under the No Action Alternative and the action alternatives, and the geographic locations of water delivery from the Colorado River system will not change because of this action. Since the nature of the proposed federal action will not impact the potential for spreading and/or continued presence of these invasive mussels, and since conditions related to this issue will be the same under the No Action Alternative and the action alternatives, this issue is not discussed further in this Final EIS.

Action Alternatives. While the action alternatives differ from the No Action Alternative to some degree, all action alternatives exhibit similar reservoir elevation fluctuations as compared to the No Action Alternative. Temporary establishment and loss of vegetation and wildlife habitat below the full pool elevation would occur similarly under all alternatives. In general, higher reservoir elevations such as those associated with the Reservoir Storage Alternative would decrease exposed shoreline available for plant colonization by decreasing the distance between permanent shoreline vegetation and the lake edge, and would thus provide less opportunity for temporary desirable and undesirable plant communities to develop. Lower elevations such as those associated with the Water Supply Alternative would increase the distance between permanent shoreline vegetation and aquatic habitats, which would increase shoreline available for plant colonization, but would also increase the distance wildlife would need to travel between permanent cover habitat and the lake edge. The descriptions below are limited to the 10^{th} and 50^{th} percentiles, as elevations at the 90^{th} percentile under the action alternatives are virtually unchanged from those under the No Action Alternative for both Lake Powell and Lake Mead.

Preferred Alternative, Lake Powell. Compared to the No Action Alternative, the Preferred Alternative results in somewhat higher elevations during the interim period and somewhat lower elevations in the long term at the 10^{th} percentile; and somewhat lower elevations in the interim period at the 50^{th} percentile.

Preferred Alternative, Lake Mead. At the 10^{th} percentile, the Preferred Alternative is generally unchanged from the No Action Alternative, with the exception of somewhat higher elevations from 2018 through 2032. At the 50^{th} percentile, 2009 through 2025 have somewhat higher elevations. The Preferred Alternative is bracketed by the high and low reservoir elevations of the other action alternatives for all percentile scenarios, through both the interim period and the –post-interim period.

Basin States Alternative, Lake Powell. With only a few minor exceptions, the Basin States Alternative has reservoir elevations similar to the Preferred Alternative at the 10^{th} and 50^{th} percentiles.

Basin States Alternative, Lake Mead. From 2010 through 2017, the Basin States Alternative has somewhat lower elevations than the No Action Alternative at both the 10^{th} and 50^{th} percentiles. In other years, the Basin States Alternative mimics the Preferred Alternative.

Conservation Before Shortage Alternative, Lake Powell. With a few minor exceptions, the Conservation Before Shortage Alternative has reservoir elevations similar to the Preferred Alternative at the 10^{th} and 50^{th} percentiles.

Conservation Before Shortage Alternative, Lake Mead. The Conservation Before Shortage Alternative has reservoir elevations similar to the Basin States Alternative at the 10^{th} and 50^{th} percentiles.

Water Supply Alternative, Lake Powell. Through 2014, the Water Supply Alternative elevations are somewhat higher than the No Action Alternative at the 10^{th} percentile, and significantly lower throughout the remainder of the interim period and through the modeling period. At the 50^{th} percentile, elevations are similar through 2010, somewhat to significantly lower through approximately 2032, and similar through the remainder of the modeling period.

Water Supply Alternative, Lake Mead. At the 10th percentile, the Water Supply Alternative results in somewhat lower reservoir elevations than the No Action Alternative from 2010 through 2017, somewhat higher elevations from 2018 through 2023, and generally mimics the No Action Alternative for the remainder of the modeling period. At the 50th percentile, this alternative results in somewhat lower elevations through 2035, and unchanged elevations for the remainder of the modeling period.

The lower reservoir elevations that may occur under the Water Supply Alternative fall outside the potential range of the No Action Alternative. At these low reservoir elevations, there would be a greater potential for sediment delta headcutting at the inflow areas causing movement of sediment further into the reservoirs. The Water Supply Alternative would have the greatest potential effect on these deltas due to increased reservoir drawdown, which could potentially impact vegetation and wildlife habitat. These impacts may occur in the interim period and the post-interim period. The lower lake elevations under the Water Supply Alternative may remain lower than under the No Action Alternative until approximately 2036 for Lake Powell and until 2040 for Lake Mead at the 50th percentile, and until 2055 for Lake Powell at the 10th percentile.

Reservoir Storage Alternative, Lake Powell. Reservoir elevations under the Reservoir Storage Alternative are somewhat higher than under the No Action Alternative throughout the interim period at the 10th percentile. Beginning in 2034, there is little variation between the Reservoir Storage Alternative and the No Action Alternative throughout the remainder of the modeling period. At the 50th percentile, lake elevations under the Reservoir Storage Alternative are slightly higher than under the No Action Alternative from 2017 through 2042, and unchanged in other years.

Reservoir Storage Alternative, Lake Mead. Reservoir elevations are somewhat higher through 2045 at the 10th percentile, and through 2035 at the 50th percentile.

4.8.3.2 Glen Canyon Dam to Lake Mead

No Action Alternative. Data on modeled Glen Canyon Dam releases are provided in Figures P-BCR-8 through P-BCR-19 in Appendix P. The range of releases is similar to the range of historic annual flows observed from 2000 to the present (Section 3.3, Figure 3.3-2), though lower than the high water years between 1995 and 2000. Therefore, the release conditions which the vegetation and wildlife downstream of Glen Canyon Dam have experienced since 2000 would continue into the future at these percentiles. Vegetation and wildlife are likely adjusting or have adjusted to these lower flows. Stabilized lower flows have been observed to favor riparian vegetation development at numerous locations in the Western United States (Reclamation 1995; Gloss et al. 2005). This trend benefits species that utilize shrubby riparian vegetation. The modeled release trends indicate that the magnitude of average monthly releases under the No Action Alternative would likely be unchanged to somewhat lower in the future through the modeling period at the 10th, 50th, and 90th percentiles. The only noticeable exception to these trends occurs at the 90th percentile in June.

Action Alternatives. From the end of the interim period through the modeling period, the differences in modeled releases for the action alternatives at the 10th, 50th, and 90th percentiles are well within both daily and monthly release variations (modeled and historical), and generally mimic the modeled releases under the No Action Alternative. It is therefore anticipated that none of the action alternatives will have significant positive or negative impacts on riparian vegetation or wildlife in the Glen Canyon Dam to Lake Mead river reach in the post-interim period when compared to the No Action Alternative.

During the interim period, releases under the action alternatives at the 10th percentile are generally unchanged or lower than under the No Action Alternative, with the Reservoir Storage Alternative being the closest to the No Action Alternative. Maximum 10th percentile release reductions are typically between 700 and 2,000 cfs, though the Water Supply Alternative may be lower than the No Action Alternative by up to 3,800 cfs in July and September. Releases under the Preferred Alternative are lower by as much as 2,000 cfs between July and December at the 10th percentile. Low flows have the greatest likelihood of negatively impacting riparian and marsh vegetation and wildlife that utilize such habitats. The impacts would be minor because for the most part, these reduced releases remain within the range of annual fluctuation and would be temporary. The impacts may cause stress to phreatophytes, but would not be expected to cause significant plant die-off. These impacts would affect obligate phreatophytes such as willow more than facultative phreatophytes such as saltcedar. Thus, these minor impacts may favor continued saltcedar expansion, though saltcedar is expanding along the Colorado River under existing conditions.

Because Glen Canyon Dam releases under the action alternatives generally return to the releases under the No Action Alternative near the end of the interim period, these impacts would end after the interim period. However, the effects on phreatophytes and continued saltcedar expansion may be observable even after the releases return to those under the No Action Alternative. Minor negative impacts to riparian vegetation at the lower 10th percentile of releases under all alternatives, including the No Action Alternative, would in turn impact the habitats for herptofauna, small mammals, waterfowl, and songbirds that utilize those habitats. Snakes found downstream of Glen Canyon Dam are typically found in drier portions of the reach and should not be impacted by these alternatives. Lake Powell releases at the 50th percentile of lake elevations would have temperatures under the action alternatives similar to those under the No Action Alternative and thus would cause no temperature related impacts to amphibians along the river. Only the Water Supply Alternative may result in substantially higher temperatures in some years and may provide some thermal benefit to amphibian reproduction along the river (Tables P-BCR-1 through P-BCR-3). It would be difficult to quantitatively measure these potential impacts as the impacts to river temperatures and vegetation may be temporary and minor and thus indirect impacts to species using those habitats would be small. These potential small habitat impacts are unlikely to in turn impact large mammals in the canyon. Due to the potential for minor impacts to riparian vegetation, all the alternatives would have similar minor impacts to wildlife in the Glen Canyon Dam to Lake Mead river ranch.

At the 50th percentile, releases under the Basin States, Conservation Before Shortage, and Water Supply alternatives, and the Preferred Alternative, are generally greater than under the No Action Alternative. Differences of as much as 3,800 cfs occur during May through September under the Water Supply Alternative, with slightly smaller increases under the other action alternatives. The Reservoir Storage Alternative releases are virtually unchanged from the No Action Alternative releases at the 50th percentile. Since the 50th percentile releases are well within the range of historical annual releases, negative impacts to permanent riparian vegetation and wildlife habitat are expected to be minimal, though higher summer releases may inhibit the reestablishment of some herbaceous vegetation in riparian areas that have been exposed during recent low release years. Modestly higher seasonal flows may expand marshy areas, and benefit existing saltcedar, willow, and shrub habitat both by inundation and contributions to groundwater.

At the 90th percentile, the magnitude of flows exceeding those under the No Action Alternative that may occur under the action alternatives is relatively small, with the exception of the Reservoir Storage Alternative. Releases under the Reservoir Storage Alternative in June may be up to 6,800 cfs above releases under the No Action Alternative and approach 30,000 cfs. Unusually high flows may cause scouring of vegetation that may have developed at the lower levels on the river banks under previously lower flow conditions. These flows, however, are below the levels of historical high flows which have exceeded 40,000 cfs. Despite the potential scouring effects from these higher flows, they provide an overall benefit to vegetation and wildlife in the long term.

Releases under the Preferred Alternative at the 90th percentile are somewhat lower than under the No Action Alternative at the 90th percentile in July and September through December, and generally somewhat higher during January through May.

4.8.3.3 Hoover Dam to Davis Dam

No Action Alternative. The Hoover Dam to Davis Dam reach consists primarily of the reservoir pool of Lake Mohave, the elevation of which is controlled by operation of Davis Dam. Lake Mohave and Lake Havasu are operated on a monthly rule curve and end-of-month target elevations and therefore significant fluctuations in reservoir elevations do not occur. No change in vegetation or wildlife is expected over the interim period or the modeling period. Information on monthly Hoover Dam releases is provided in Figures P-BCR-20 through P-BCR-31.

Action Alternatives. Elevations of these two reservoirs under the action alternatives would not deviate from elevations under the No Action Alternative. Accordingly, there would be no impacts to vegetation or wildlife at these reservoirs. Because vegetation is limited in the Hoover Dam to Lake Mohave river reach, potential flow differences among alternatives in this reach of the Colorado River would not substantially impact vegetation or wildlife.

4.8.3.4 Davis Dam to Parker Dam

No Action Alternative. Fluctuations of monthly flows downstream of Davis Dam of several thousand cfs have occurred in the recent past and will continue into the future. Vegetation and wildlife habitat along the Colorado River continuously make minor adjustments as these flows fluctuate. Annual median releases from Davis Dam under the No Action Alternative show a slight downward trend through 2040 (Section 4.3, Figure 4.3-32). Accordingly, the lower releases could potentially cause a corresponding decline in groundwater levels along the 39 mile section of the Colorado River that extends from Davis Dam to Lake Havasu.

Action Alternatives. In general, both lower and higher monthly releases under the action alternatives would have similar impacts to vegetation and wildlife as discussed for the Glen Canyon Dam to Lake Mead reach. At the 10^{th} and 50^{th} percentiles, release rates for Davis Dam fall within a relatively narrow band for all months. Average monthly Davis Dam releases under all alternatives are provided in Figures P-BCR-32 through P-BCR-43. The differences in monthly releases under the Preferred Alternative and under the No Action Alternative are generally small, and are not expected to impact vegetation or wildlife at these percentiles in either the interim period or the post-interim period. The Reservoir Storage Alternative results in lower releases during the interim period, while the Water Supply Alternative results in higher releases. The higher releases would benefit vegetation and wildlife, but release differences are small, and these benefits would be minor. Slightly lower releases under the Reservoir Storage Alternative may have minor negative impacts on vegetation and wildlife as compared to releases under the No Action Alternative. Similarly to the Preferred Alternative, the Basin States and Conservation Before Shortage alternatives essentially follow the No Action Alternative, and where there are differences they are infrequent, small differences. Therefore, the Basin States and Conservation Before Shortage alternatives, and the Preferred Alternative, should have no measurable impacts on vegetation in the Davis Dam to Parker Dam river reach.

At the 90^{th} percentile, the Reservoir Storage Alternative may result in higher releases due to increased flood control releases not projected under the other alternatives. These releases typically occur in winter months, outside the growing season. These flows may be up to 6,000 cfs greater than under the No Action Alternative at the 90^{th} percentile, but would not be large enough to cause significant scouring or over-bank flooding. Thus, no substantial riparian impacts are expected. The Preferred Alternative may result in somewhat higher releases in January and February in the interim period, and somewhat lower or unchanged releases in the modeling period at the 90^{th} percentile. The differences would be isolated and temporary, and are not expected to significantly impact vegetation or wildlife along this reach. With the exception of January, modeled releases for the No Action Alternative and the action alternatives converge relatively quickly after the end of the interim period. Releases and their effects under the action alternatives generally return to those under the No Action Alternative relatively soon after the interim period, though minor effects on vegetation may be observed beyond the interim period.

A comparison of annual median release under each action alternative to the annual median release under the No Action Alternative showed minor reductions in river stage and corresponding groundwater levels (Section 4.3). The Reservoir Storage Alternative results in the greatest reduction in annual median release from Davis Dam (Section 4.3, Figure 4.3-32) that may lower groundwater levels during the interim period by as much as 0.25 to 0.50 foot for gaining and losing reaches, respectively. Sustained decreases in groundwater levels of this magnitude might have minor negative effects on cottonwood-willow and marsh communities as compared to the No Action Alternative. The Water Supply Alternative results in annual median releases that are somewhat higher than under the No Action Alternative through the interim period, and may have minor positive impacts on cottonwood-willow and marsh vegetation during this period due to higher groundwater levels. The Basin States and Conservation Before Shortage alternatives, and the Preferred Alternative, result in annual median releases somewhat lower than but close to those under the No Action Alternative through 2012, and otherwise generally mimic the No Action Alternative in the interim and post-interim periods. These alternatives are therefore not expected to impact cottonwood-willow or marsh vegetation.

4.8.3.5 Parker Dam to Imperial Dam

No Action Alternative. Fluctuations of monthly flows downstream of Parker Dam of several thousand cfs have occurred in the recent past, and will continue into the future. Vegetation and wildlife habitat along the Colorado River continuously make minor adjustments as these flows fluctuate. Annual median releases from Parker Dam under the No Action Alternative show a slight downward trend through 2040 (Section 4.3, Figure 4.3-37), which may effect groundwater levels.

Action Alternatives. In general, both lower and higher monthly releases under the action alternatives would have similar impacts to vegetation and wildlife as discussed for the river reach between Glen Canyon Dam and Lake Mead. Release rates at the 10th and 50th percentiles for Parker Dam fall within a relatively narrow band for all months. Average monthly Parker Dam releases are provided in Figures P-BCR-44 through P-BCR-55. The differences in releases under the Preferred Alternative and under the No Action Alternative are generally small, and are not expected to impact vegetation or wildlife at these percentiles in either the interim or the modeling period. The Reservoir Storage Alternative results in lower releases during the interim period, while the Water Supply Alternative results in higher releases. The higher releases would benefit vegetation and wildlife, but release differences are small, and these benefits would be minor. Slightly lower releases under the Reservoir Storage Alternative may have minor negative impacts on vegetation and wildlife compared to releases under the No Action Alternative. Similarly to the Preferred Alternative, releases under the Basin States and Conservation Before Shortage alternatives essentially follow the releases under the No Action Alternative, and where there are differences they are infrequent, small differences. Therefore, changes in monthly releases from Parker Dam under the Basin States and Conservation Before Shortage alternatives, and the Preferred Alternative, should have no substantial impacts on vegetation in the river reach between Parker Dam and Imperial Dam.

At the 90th percentile, the Reservoir Storage Alternative may create higher releases due to increased flood control releases not modeled under other alternatives. These releases typically occur in winter months, outside the growing season. These flows may be up to 4,000 cfs higher than those under the No Action Alternative at the 90th percentile, but would not be large enough to cause significant scouring or over-bank flooding. Thus, no substantial riparian impacts are expected. The Preferred Alternative may result in somewhat higher releases in January and February in the interim period, and somewhat lower or unchanged releases in the modeling period at the 90th percentile. The differences would be isolated and temporary, and are not expected to significantly impact vegetation or wildlife along this river reach. With the exception of January, modeled releases under the No Action Alternative and the action alternatives converge relatively quickly after the end of the interim period. Releases and other effects under the action alternatives generally return to the those the No Action Alternative relatively soon after the interim period, though minor effects on vegetation of interim period conditions may be observed beyond the interim period.

The Reservoir Storage Alternative results in annual median releases from Parker Dam that are lower than under the No Action Alternative (Section 4.3, Figure 4.3-37), which may lower groundwater levels throughout the interim period by as much as 0.15 to 0.30 foot for gaining and losing reaches, respectively. Sustained decreases in groundwater levels of this magnitude might have minor negative effects on cottonwood-willow and marsh communities as compared to those under the No Action Alternative. The Water Supply Alternative results in annual median releases that mimic or are slightly higher than under the No Action Alternative through the interim and modeling periods, which may have minor positive impacts on cottonwood-willow and marsh vegetation from 2016 through 2026 due to higher groundwater levels. Annual median releases under the Basin States and Conservation Before Shortage alternatives, and the Preferred Alternative, are generally bracketed between the Reservoir Storage Alternative and the No Action Alternative, are all somewhat lower than under the No Action Alternative through the interim and post-interim periods. These slightly lower groundwater levels may result in minor negative impacts on marsh and riparian communities.

4.8.3.6 Imperial Dam to NIB

Most of the water delivered to Mexico is diverted at Imperial Dam, conveyed via the AAC, and then returned to the Colorado River through the Pilot Knob and Siphon Drop Powerplants and their respective wasteway channels, which discharge to the Colorado River mainstream 2.1 and 7.6 miles upstream of the NIB, respectively (Section 3.3). The proposed federal action will not alter the operation of these diversions and wasteways and therefore will not have an effect on the river reach between Imperial Dam and the NIB.

4.8.3.7 NIB to SIB

No Action Alternative. The frequency and magnitude of flows are important factors in maintaining riparian habitat and wildlife in the river reach between Morelos Diversion Dam and the SIB; however, the potential biological effects downstream of the NIB cannot be specifically determined because of the uncertainty of water use once it flows to the NIB and becomes available to Mexico.

The hydrologic models for this Final EIS (Section 4.2) have assumed that any water in excess of Mexico's scheduled normal or surplus deliveries would not be diverted by Mexico but would continue down the Colorado River channel from Morelos Diversion Dam to the SIB. This assumption results in the probability of flows passing Morelos Diversion Dam that might be somewhat higher than may actually occur. The potential impacts discussed in the following section are based on this assumption.

Under the No Action Alternative, flows downstream of Morelos Diversion Dam will continue to be primarily the result of dam leakage and agricultural return flows. Flows past Morelos Diversion Dam will continue to be relatively rare events (Figure P-BCR-56). It is expected that riparian and marsh vegetation and wildlife will continue to experience some year-round flow in the upstream part of this reach and sporadic flow in the downstream part of this reach under the No Action Alternative. Thus, historical conditions will generally continue under the No Action Alternative.

Action Alternatives. During the interim period and beyond, the Basin States and Water Supply alternatives, and the Preferred Alternative, are just as likely to result in excess flows downstream of Morelos Diversion Dam as the No Action Alternative, and would therefore have no impact on this reach as compared to the No Action Alternative. Further, the probabilities of occurrence for these excess flows are low and range between ten percent and 15 percent (Figure P-BCR-56). The magnitude of excess flows past Morelos Diversion Dam is zero for approximately 80 to 90 percent of the model traces between 2008 and 2060 (Section 4.3, Figure 4.3-39). The magnitude of these excess flows under the Reservoir Storage Alternative may be higher by as much as one mafy than under the No Action Alternative. The magnitude of these excess flows under the Conservation Before Shortage Alternative may be higher by as much as 0.35 mafy than under the No Action Alternative (Section 4.3, Figure 4.3-43).

Due to modeling assumptions under the Conservation Before Shortage and Reservoir Storage alternatives, water is also delivered to Mexico through this river reach via periodic flows of about 40 kafy to 200 kafy (Appendix M). These pulse flows[1] would

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[1] These flows were modeled as part of the storage and delivery mechanism under the Conservation Before Shortage and Reservoir Storage alternatives. The modeling assumptions were utilized in this Final EIS in order to analyze the potential impacts to environmental resources of the storage and delivery mechanism, particularly with regard to reservoir elevations and river flow impacts. The use of these modeling assumptions does not represent any determination by Reclamation as to whether, or how, these releases could be made under current management of the Colorado River.

occur approximately every fifth year during the interim period only and other flows that could be used for environmental, domestic, or agricultural purposes would also be released every five years. The probability of flows past Morelos Diversion Dam under these two alternatives returns to that under the No Action Alternative after the interim period. These flows would benefit vegetation and wildlife downstream of Morelos Diversion Dam because they would increase river flow, scour and redistribute sediment, and provide opportunities for establishment of cottonwood-willow and marsh vegetation. These fluvial processes are valuable to aquatic and riparian systems in the long term, though temporary losses of riparian or marsh vegetation may occur from scouring, which could temporarily disrupt wildlife.

Table 4.8-1 summarizes impacts to vegetation and wildlife under the action alternatives relative to the No Action Alternative.

Table 4.8-1
Vegetation and Wildlife Impact Summary
Comparison of Action Alternatives to No Action Alternative

Location	Alternative	Impact	Rationale
Lake Powell and Lake Mead	Preferred Alternative	Minor - positive	Potential for higher reservoir elevations, especially at the 10th percentile in Lake Powell during the interim period.
	Conservation Before Shortage, Basin States	No impact to Minor - Positive	Elevations and fluctuation similar to those under the No Action Alternative and the Preferred Alternative.
	Water Supply	Minor – negative	Reservoir elevations tend to be lower than under the No Action Alternative, with increased opportunities for undesirable plants to colonize shoreline and for sediment delta headcutting. Lower elevations would increase distance between shoreline vegetation and the lakes.
	Reservoir Storage	Minor- positive	Elevations tend to be higher than under the No Action Alternative, with decreased opportunities for undesirable plants to colonize shoreline and for sediment delta headcutting. Elevation fluctuations inundate all vegetation below full pool elevation. Higher elevations would decrease distance between shoreline vegetation and lakes.
Glen Canyon Dam to Lake Mead	All action alternatives	Minor – negative	Decreased releases at the 10th percentile (for all alternatives there are similar reductions overall). Release differences are within the range of recent history and annual fluctuation.
Hoover Dam to Davis Dam and Lake Havasu to Parker Dam	All action alternatives	No impact	Relatively small Hoover Dam release differences and very limited vegetation upstream of Lake Mohave. Monthly rule curves at Lake Mohave and Lake Havasu prevent elevation deviations from the No Action Alternative.

Table 4.8-1
Vegetation and Wildlife Impact Summary
Comparison of Action Alternatives to No Action Alternative

Location	Alternative	Impact	Rationale
Davis Dam to Parker Dam	Conservation Before Shortage, Basin States, Preferred Alternative	No impact	Monthly releases closely follow the No Action Alternative. Annual median Davis Dam release is similar to the No Action Alternative.
	Water Supply	Minor-positive	Monthly releases higher than under the No Action Alternative at the 10th and 50th percentiles. Higher annual median release from Davis Dam.
	Reservoir Storage	Minor – Negative	Monthly releases lower than under the No Action Alternative at the 10th and 50th percentiles. Lower annual median release from Davis Dam.
Parker Dam to Imperial Dam	Water Supply	Minor - Positive	Monthly releases closely follow the No Action Alternative. Annual median Parker Dam release is similar to or higher than under the No Action Alternative.
	Basin States, Conservation Before Shortage, Reservoir Storage, Preferred Alternative	Minor – Negative	Monthly releases lower than under the No Action Alternative at the 10th and 50th percentiles (the Reservoir Storage Alternative has the greatest reduction; the Basin States Alternative has the least reduction). The Reservoir Storage Alternative higher flows in the winter are unlikely to have substantial benefits due to channel capacity. Annual median Parker Dam releases are lower than under the No Action Alternative.
	All action alternatives	No impact	Flow changes are routed through AAC and Pilot Knob/Siphon Drop Powerplants rather than the Colorado River downstream of Imperial Dam.
Imperial Dam to NIB	Basin States, Water Supply, Preferred Alternative	No impact	Probability of excess flows past Morelos Diversion Dam is very close to that of the No Action Alternative.
NIB to SIB	Reservoir Storage, Conservation Before Shortage	Moderate – positive	Relatively likely high flows expected past Morelos Diversion Dam, which would benefit the riparian corridor.

4.8.4 Special Status Species

4.8.4.1 Lake Powell

No Action Alternative. Fluctuations of Lake Powell elevations would continue into the future, precluding the development of stable vegetated terrestrial habitats below elevation 3,700 feet msl because vegetation that develops would be periodically dewatered or inundated.

Fish. The Colorado pikeminnow, bonytail chub, razorback sucker and flannelmouth sucker all occur in Lake Powell, primarily at the inflow areas of the Colorado River and the San Juan River. The flannelmouth sucker population has been decreasing since the reservoir was formed (Reclamation 2000). Low reservoir elevations increase the amount of riverine habitat available for these species in the river inflow areas, which may be a temporary benefit to these fish. In addition, when the lake elevation is below 3,660 feet msl, a waterfall becomes exposed in the San Juan River where it enters Lake Powell. This waterfall forms a barrier to upstream movement of non-native fish that can prey upon or compete with special status fish in the San Juan River (i.e., Colorado pike minnow and razorback sucker). The waterfall, however, also would prevent native fish that enter the reservoir from the river from moving back into the river. Thus, reservoir elevations below 3,660 feet msl could provide a minor benefit to special status fish in the San Juan River. The probability that Lake Powell will be at or below elevation 3,660 feet msl generally increases during the interim period but levels off at approximately 50 percent near the end of the modeling period (Figure P-BCR-57).

Birds. Special status birds that currently may be affected by elevation fluctuations of Lake Powell include California condor, bald eagle, osprey, belted kingfisher, Clark's grebe, and American peregrine falcon. California condors are scavengers, primarily on large mammals and sometimes on fish. The lower reservoir elevations projected for the future may expose additional shoreline for scavenging.

Bald eagles in this area are primarily winter residents that feed on fish, waterfowl and carrion. Though there may be effects on fisheries as reservoir elevations decline, no effects on the population of fish are anticipated. Therefore, this food source is expected to remain available for bald eagles under the No Action Alternative.

Ospreys are a rare transient in summer along the Colorado River. However, they could potentially utilize Lake Powell during migration. Fluctuating reservoir elevations would have no direct impacts to ospreys, and no substantial indirect effects on food sources (fish) are expected.

Peregrine falcons may utilize Lake Powell for hunting songbirds, bats and small mammals. Reservoir elevation fluctuations would not directly impact peregrine falcons. Nearby populations in the Grand Canyon are considered stable and the species was delisted from federal listing in 1999 (Gloss et al. 2005).

Belted kingfishers inhabit riparian areas in Arizona and mainly consume fish. Kingfishers could be affected as fish availability fluctuates over time. Given the gradual downward trend for Lake Powell elevations in the future, it is anticipated that fish populations would be able to adjust to the changing conditions. Increased inflow areas as the elevations decline may provide improved shallow-water hunting area.

Clark's grebe inhabit marshes and may be found in marsh habitat at Lake Powell inflow areas. They are common breeders in Utah and utilize lakes and shoreline vegetation for breeding habitat. The decline of reservoir elevations projected in the future under the No Action Alternative may dewater marshes at the inflow areas, causing temporary loss of marsh habitat until the marsh re-establishes at a lower elevation, or the reservoir elevations recover.

Mammals. Special status mammals that may utilize Lake Powell include spotted bat, Townsend's big-eared bat, pale Townsend's big-eared bat, Yuma myotis, Allen's big-eared bat, western red bat, and occult little brown bat. All of these species may utilize riparian habitats around the shoreline of Lake Powell. As lake elevations fluctuate, these habitats may be dewatered or inundated and localized effects on food source populations may occur. Given their wide-ranging nature, these species would not be expected to be substantially impacted under the No Action Alternative or the action alternatives. Accordingly, these species are not discussed further for this reach.

Amphibians. Northern leopard frog populations are found in side canyons of Lake Powell above the fluctuating reservoir elevations (Gloss et al. 2005). These populations in habitat areas located above elevation 3,700 feet msl and would not be impacted by declining elevations of Lake Powell. However, continued fluctuations of Lake Powell elevations would likely limit marsh and riparian vegetation at the shoreline, or only allow it to establish temporarily, thus continuing to limit the potential for leopard frogs and other amphibians to utilize areas below the full pool elevation of Lake Powell.

Action Alternatives.

Fish. Flannelmouth suckers, razorback sucker, Colorado pikeminnow and bonytail chub occur in the inflow areas of the Colorado River and the San Juan River but do not spawn in Lake Powell, and fluctuating reservoir elevations under the action alternatives would be unlikely to affect habitats within the reservoir for any individuals remaining in the reservoir. For fish in the inflow areas, however, lower reservoir elevations would increase the amount of riverine habitat while higher elevations would decrease that habitat. A waterfall would be exposed in the San Juan River when Lake Powell elevation declines to 3,660 feet msl; this waterfall would be a barrier to upstream fish movement and limit the benefits to native fish below that elevation. The changes in the extent of habitat under the action alternatives were estimated using modeling results for March, July and September at the 90th, 50th and 10th percentiles of reservoir elevations (Figures P-WQA-6, P-BCR-1 and P-BCR-2). The 90th percentile elevations are essentially the same under all alternatives and are not analyzed here. The waterfall in the San Juan River would be exposed at the 10th percentile of reservoir elevations under all alternatives, and under all but the Reservoir Storage Alternative at the 50th percentile of reservoir elevations. Thus, benefits of increased riverine habitat to native fish would be limited to the Colorado River and any other smaller tributaries that discharge to Lake Powell.

Preferred Alternative. Lake Powell elevations under the Preferred Alternative could be up to 32 feet higher than under the No Action Alternative until about 2025, and then up to 17 feet lower until about 2060 at the 10th percentile. Reservoir elevations at the 50th percentile would be up to 17 feet lower than under the No Action Alternative until about 2045 at which time reservoir elevations under the Preferred Alternative and the No Action Alternative would become equal. Thus, the Preferred Alternative could provide minor benefits to native fish during those times when Lake Powell elevations are lower than under the No Action Alternative. The probability that the San Juan River waterfall will be exposed under the Preferred Alternative is similar or higher than the probability that the waterfall will be exposed under the No Action Alternative (Figure P-BCR-57).

Basin States Alternative. Under this alternative Lake Powell elevations would be similar to those described for the Preferred Alternative, but the elevations could be slightly (up to two feet) lower. Benefits to native fish would be essentially the same as under the Preferred Alternative. The probability that the San Juan River waterfall will be exposed under the Basin States Alternative is similar or higher than the probability that the waterfall will be exposed under the No Action Alternative (Figure P-BCR-57).

Conservation Before Shortage Alternative. Lake Powell elevations would generally be within one foot of those under the Basin States Alternative, and benefits to native fish would be the same as under the Basin States Alternative. The probability that the San Juan River waterfall will be exposed under the Conservation Before Shortage Alternative is similar to or higher than the probability that the waterfall will be exposed under the No Action Alternative (Figure P-BCR-57).

Water Supply Alternative. Lake Powell elevations would remain higher than those under the No Action Alternative until about 2015 by up to about 21 feet at the 10^{th} percentile. After 2015, the elevations would be up to 65 feet lower than under the No Action Alternative to the end of the modeling period (2060). At the 50^{th} percentile, reservoir elevations would be up to 40 feet lower than under the No Action Alternative from about 2010 until 2042. This alternative would provide the most riverine habitat of all the alternatives considered. The probability that the San Juan River waterfall will be exposed under the Water Supply Alternative is similar to or higher than the probability that the waterfall will be exposed under the No Action Alternative (Figure P-BCR-57).

Reservoir Storage Alternative. Under this alternative, Lake Powell elevations would remain higher than those under the No Action Alternative at the 10^{th} and 50^{th} percentiles until about 2040 or later. Reservoir elevations would be up to 31 feet higher at the 10^{th} percentile and 10 feet higher at the 50^{th} percentile. Thus, the Reservoir Storage Alternative would provide less riverine habitat for native fish than any of the other alternatives, including the No Action Alternative, and result in a minor negative impact. The probability that the San Juan River waterfall will be exposed under the Reservoir Storage Alternative is lower than the probability that the waterfall will be exposed under the No Action Alternative (Figure P-BCR-57).

Birds. Since bald eagles, peregrine falcons, California condor and osprey are all wide-ranging species that utilize many different habitat types in the area, none of the action alternatives differ substantially enough to impact these species at Lake Powell.

Clark's grebe would be impacted predominantly by impacts to marsh habitats. The Water Supply Alternative would have a minor negative impact on vegetation, including marshes at the inflow areas, and the Reservoir Storage Alternative would have a minor-positive impact on vegetation. These impacts may occur during the interim period and the post-interim period. Clark's grebe would not be impacted under the Basin States and Conservation Before Shortage alternatives, and the Preferred Alternative.

Belted kingfishers would be most impacted by potential changes in fish food supplies. Substantial impacts to fish food supplies at Lake Powell are not anticipated under the action alternatives, thus no impacts to belted kingfishers are anticipated.

Amphibians. Northern leopard frog populations are found in side canyon areas located above elevation 3,700 feet msl, therefore, the special status amphibians at Lake Powell would not be impacted under the action alternatives.

Table 4.8-2 summarizes the impacts to special status species under the action alternatives relative to the No Action Alternative.

Table 4.8-2
Lake Powell Special Status Species Impact Summary
Comparison of Action Alternatives to No Action Alternative

Species	Alternative	Impact	Rationale
Razorback sucker, bonytail, Colorado pikeminnow, flannelmouth sucker	Water Supply, Conservation Before Shortage, Basin States, Preferred Alternative	Minor - positive	Reservoir elevations tend to be lower than under the No Action Alternative, increasing riverine conditions at the inflows. Alternatives are more likely to result in exposure of waterfall at San Juan River inflow.
	Reservoir Storage	Minor-negative	Reservoir elevations tend to be higher than under the No Action Alternative, decreasing riverine conditions at the inflows. Lower likelihood of exposure of waterfall at San Juan River inflow.
Bald eagle, peregrine falcon, osprey, California condor, belted kingfisher	All action alternatives	No impact	Wide ranging species and action alternatives do not differ substantially enough to cause indirect impacts.
Clark's grebe	Conservation Before Shortage, Basin States, Preferred Alternative	No impact	Reservoir elevations trend close to those under the No Action Alternative. Impacts to marsh not anticipated.
	Water Supply	Minor - negative	Lower reservoir elevations would have minor negative impact on marshes at the inflows, by increased likelihood of sediment delta headcutting.
	Reservoir Storage	Minor – positive	Higher reservoir elevations would have minor positive impact on marshes at the inflows, by decreased likelihood of sediment delta headcutting.
Mammals	All action alternatives	No impact	Wide-ranging species under the action alternatives do not differ substantially enough to cause indirect impacts.
Northern leopard frog	All action alternatives	No Impact	Known populations above Lake Powell elevation fluctuations.

4.8.4.2 Glen Canyon Dam to Lake Mead

No Action Alternative. Under the No Action Alternative, the magnitude of annual releases from Glen Canyon Dam would remain relatively stable during the interim period, but would be reduced over the later years of the modeling period (90th percentile) as Upper Basin depletions increase (Section 4.3, Figure 4.3-12). The magnitude of monthly releases from Glen Canyon Dam at the 90th percentile also trend downward over the later modeling period in some months (Figures P-BCR-8 through P-BCR-19). Reduced river flows have the potential to affect phreatophytes, marshes, and associated special status species.

Plants. Grand Canyon evening primrose grows on beaches along or near the mainstream Colorado River in the vicinity of Separation Canyon and downstream of Diamond Creek (Reclamation 2000). Lower releases could allow this species to colonize lower beaches exposed during reduced releases. Reduced high flows would favor encroachment of riparian vegetation towards the Colorado River, which would compete with the species. High flows and sediment, which are needed to maintain beach habitats and discourage riparian vegetation encroachment, would continue to be limited in the future. Beach habitat occupied by this species is also utilized by recreationists, which limits Grand Canyon evening primrose establishment.

Invertebrates. The Kanab ambersnail occurs in semi-aquatic habitat associated with springs and seeps. In the Grand Canyon, Kanab ambersnail were originally known to occur only at Vasey's Paradise, a large perennial spring. As part of an effort to recover the species, Kanab ambersnails were translocated from Vasey's Paradise to three other locations. One of the criteria used to select these sites was that it be above the elevation of any potential future flood flows past Glen Canyon Dam. These translocated populations would not be affected by the proposed federal action. The Vasey's Paradise population and vegetation are not flooded until flows exceed 17,000 cfs (Reclamation 2002b). Monthly releases under the No Action Alternative may exceed 17,000 cfs for more than a single year in January, February, May, June, July, August, September, and December at the 90th percentile of releases (Figures P-BCR-8 through P-BCR-19).

Niobrara ambersnail occur in wetland habitats at several locations downstream of Glen Canyon Dam. The population near Lees Ferry is subject to inundation from even moderate flows of the Colorado River (greater than 25,000 cfs), and more than 90 percent of the entire habitat is inundated at 45,000 cfs or more. The Indian Gardens population persisted through the 1996 experimental flow. The population has not been monitored since May 1998 and March 1999 at which time it was abundant. However, flows exceeded 22,000 cfs for extended periods in the summer of 1998 and in May 1999, and no snails were found during habitat searches in those periods. Flows over 20,000 cfs inundate the Indian Gardens habitat (Arizona Game and Fish 2004). Monthly releases under the No Action Alternative may exceed 20,000 cfs at the 90th percentile releases in June, July, August, September, and December, which could cause a loss of wetland vegetation and individual snails.

MacNeill's sootywing skipper is a butterfly found along the Colorado River from southern Utah and Nevada to Arizona and southeastern California (Reclamation 1996b). Communication with Mr. Larry Stevens, the Curator of Ecology at the Museum of Northern Arizona indicated that potential sootywing skipper habitat does not occur upstream of Lake Mead (Stevens 2007, personal communication). Mr. Stevens has performed surveys for various butterflies in northern Arizona. Therefore, no impacts to this species are anticipated in the Grand Canyon.

Fish. Glen Canyon Dam releases would continue to follow the guidelines provided in the 1996 Glen Canyon Dam ROD and under the No Action Alternative; the annual releases have a low probability of declining below 8.23 mafy in the future (Section 4.3, Table 4.3-11). Thus, the extent and physical characteristics of habitat available to native special status fish species (humpback chub, bluehead sucker, flannelmouth sucker) would remain about the same under the No Action Alternative. Little information is available to quantitatively assess the potential effects of monthly release trends on the habitat of these fish. In general, the daily operations and Glen Canyon Dam releases will continue to be consistent with the 1996 Glen Canyon Dam ROD; therefore, the proposed federal action is not expected to result in substantial change in the historically observed daily releases. The potential range in hourly flows of 6,000 to 8,000 cfs would continue to occur with the larger fluctuations in December, January, July, and August (Section 4.3, Tables 4.3-13 and 4.3-14). For example, a study of backwaters in the Grand Canyon (Goeking et al. 2003) found that the number and area of backwaters present varied with river discharge between years at any given site and varied among sites within one year. Given that there is little information to quantitatively correlate differences in annual or monthly releases to impacts on the physical characteristics of special status fish habitat availability, water temperature was selected as a better metric to analyze the impacts to special status fish species. Cold river temperatures and the presence of non-native fish species appear to be the key reasons for declines in populations of some native fish species (e.g., humpback chub) in this river reach.

Glen Canyon Dam release temperatures vary depending on the reservoir elevation and other factors. These release temperatures have been modeled (Section 4.5) and comparisons of the action alternatives to the No Action Alternative are shown on Figures P-BCR-58 through P-BCR-60 in Appendix P. A comparison of modeled river temperatures at selected locations downstream of Glen Canyon Dam is shown on Figures P-BCR-61 through P-BCR-69 and Tables P-BCR-1 through P-BCR-3. Native fish, such as the humpback chub, flannelmouth sucker and bluehead sucker could benefit from warmer water temperatures during their spawning season, because releases of cold water from Lake Powell generally keep water temperatures downstream of Lake Mead below that needed for mainstream spawning to occur except in the vicinity of the Diamond Creek confluence (near Lake Mead). Thus, spawning could only occur in warmer tributaries or backwaters. When Lake Powell elevations fall below about 3,600 feet msl (approximately 10^{th} percentile of elevations), water above 15ºC (59ºF) could be released (Table P-BCR-1). This water may warm by approximately 2ºC (3.6ºF) by the time it reaches the Little Colorado

River confluence and by up to 5ºC (9ºF) near the Diamond Creek confluence (Tables P-BCR-2 and P-BCR-3). At the 10th percentile reservoir elevations, the associated release water temperatures could be warm enough for humpback chub spawning and egg incubation from approximately late May through July near Diamond Creek and in July near the Little Colorado River confluence. Growth could occur from late May through October near Diamond Creek and from July to early October near the Little Colorado River confluence.

Flannelmouth and bluehead suckers are also present in this reach of the Colorado River although they use the warmer tributaries for spawning. Only under low Lake Powell elevations (10th percentile), could suitable temperatures for spawning occur in the river for the bluehead sucker over a portion (about June through October) of their spawning season near the Little Colorado River confluence, and from about May through October near Diamond Creek. Egg incubation requires temperatures about 2ºC (3.6ºF) warmer than for spawning and thus would not occur for up to a month later in the spring, and then primarily near Diamond Creek. At the 50th percentile of reservoir elevations, water temperatures near Diamond Creek could be warm enough for their spawning from about June through October, while elevations at the 90th percentile could result in suitable spawning temperatures from about late May through September. However, temperatures may only be suitable for egg incubation in September at the 50th percentile and periodically in July and August at the 90th percentile. For flannelmouth suckers, water temperatures could be warm enough for spawning in May and June near the Little Colorado River and at Diamond Creek, and in June at Lees Ferry at the 10th percentile of reservoir elevations, while egg incubation could not occur at Lees Ferry, could occur only in June near the Little Colorado River confluence, and in May and June near Diamond Creek. Average water temperatures may be adequate to support growth of these three fish species as summarized in Table 4.8-3. Please refer to Tables P-BCR 1 through P-BCR-3 in Appendix P for further specifics on temperature.

Table 4.8-3
Months When Average Water Temperatures may be Adequate to Support Growth of Fish Under the No Action Alternative

Location	Species		
	Humpback Chub	Flannelmouth Sucker	Bluehead Sucker
Lees Ferry	August and September at the 10th percentile	August and September at the 10th percentile	July through October at the 10th percentile
Downstream of the Little Colorado River	July to early October at the 10th percentile	July to early October at the 10th percentile	Late June through October at the 10th percentile
Diamond Creek	June through October at the 10th percentile July through September at the 50th percentile July to mid September at the 90th percentile	June through October at the 10th percentile July through September at the 50th percentile July to mid September at the 90th percentile	May through October at the 10th percentile June through October at the 50th percentile Late May through September at the 90th percentile

Lake Powell elevations at the 10th percentile level pose a low potential for non-native fish to be released from Lake Powell into the Glen Canyon Dam to Lake Mead river reach. Warmer temperatures in the future under the No Action Alternative at the Diamond Creek confluence could also create conditions that would favor the upstream movement of non-native fish into the Grand Canyon from Lake Mead (e.g. striped and largemouth bass). Warmer river temperatures may also promote the movement of non-native warmwater fish from tributaries that provide inflow to this river reach. The conditions that would favor non-native warmwater species would occur infrequently and would be of short duration. Since many non-native fish prey on native fish, the potentially increased number and or higher feeding rate of non-native warmwater fish could adversely affect native species in this reach through competition or predation. However, many warmwater species of non-native fish are already present in this reach (Section 3.8, Table 3.8-4), and infrequent warmer water temperatures are unlikely to increase their numbers or change the species composition present in the long term. For cold water non-native species, such as brown trout and rainbow trout, the slight increase in water temperature at the 10th percentile would not be expected to affect their populations.

Glen Canyon Dam release temperatures have exhibited a relatively narrow seasonal variability and typically ranged from approximately 7°C to 12°C (44.6ºF to 53.6ºF) between 1990 and 2002 (Appendix F, Figure F-5). After 2002, the temperatures began to increase and the seasonal variability widened and ranged from approximately 8°C to 16°C (46.4ºF to 60.8ºF). Modeled future release temperatures under the No Action Alternative for Lake Powell elevations at the 50th percentile indicate similar potential conditions to those that began in 2002. Modeled release temperatures for Lake Powell elevations at the 10th percentile indicate the possibility of warmer release temperatures in the future (Table P-BCR-1). Warmer average river temperatures could increase the potential for expansion of the Asian tapeworm (*Bothriocephalus acheilognathi*) and anchorworm (*Lernaea cyprinacea*) in the mainstream Colorado River in some years, and could adversely affect native fish, including the humpback chub. Currently, these non-native fish parasites are found primarily in fish in the Little Colorado River and other tributaries and mostly affect native fish. Currently, and under the No Action Alternative, these parasites are less likely to infect fish in the Colorado River because water temperatures are less than optimal for these parasites.

These warmer release temperatures under the No Action Alternative also could affect the aquatic foodbase downstream of Glen Canyon Dam. However, larval chironomids, larval simuliids, *Cladophora* and *Gammarus* are key components of the aquatic foodbase downstream of Glen Canyon Dam and they are tolerant of a wide range in temperature.

The favorable temperature ranges are:

- 8°C to 25°C (46.4°F to 77°F) for larval chironomids (LeSage and Harrison 1980; Laville and Vincon 1991; Sublette et al. 1998; Stevens et al. 1998; Danks 1978; Maier et al. 1990);
- 10°C to 26°C (50°F to78.8°F) for larval simuliids (Becker 1973; Ross and Merritt 1978; Colbo and Porter 1981; Hauer and Benke 1987);
- 13°C to 17°C (55.4°F to 62.6°F) for *Cladophora* (Graham et al. 1982; Wong et al. 1978); and
- 7°C to 29°C (44.6°F to 84.2°F) for *Gammarus* (Smith 1973; Pennak and Rosine 1976; Macneil et al. 1997).

The potential future release temperatures under the No Action Alternative should be similar to or higher than historic release temperatures. The warmer releases that may occur at Lake Powell elevations at the 10th percentile may be warmer than the preference of *Cladophora* in some years, but in general, these potential warmer releases may provide some overall benefit to the aquatic foodbase. This change is anticipated to benefit special status fish that rely on these organisms as their food source. The aquatic foodbase and special status fish populations are expected to remain similar to present conditions.

Mammals. Small-footed myotis, pale Townsend's big-eared bat, Townsend's big-eared bat, spotted bat, Allen's big-eared bat, western red bat, Yuma myotis, occult little brown bat, and greater western mastiff bat all may utilize this river reach. Colorado River flows do not directly impact these species as they generally roost in caves and trees well above potential flow-related impacts. They are not obligate riparian species but may utilize such habitats for hunting. Impacts to these bat species from changes in vegetation, insect populations, from flow and water temperature changes are not likely under the No Action Alternative or the action alternatives. Accordingly, these species are not discussed further for this river reach.

Amphibians. Reduced flows in the future would not affect the spring-fed site of the leopard frog population upstream of Lees Ferry. Inundation of this site occurs at flows of approximately 21,000 cfs. Inundation of this site would potentially occur under the No Action Alternative from June through September, as releases at the 90th percentile in these months could exceed 21,000 cfs (Figures P-BCR-13 through P-BCR-16). Leopard frog reproduction has only been observed in warm (20°C or 68°F) pool and marsh areas, away from the direct influence of the Colorado River (Drost 2005). Colder pools (10°C to 15°C [50°F to 59°F]) that receive water from the Colorado River appear to be avoided. Water temperature at the spring site remains above 15°C (59°F) throughout the year and above 20°C (68°F) for several months (Spence 1996). Most of the warmer pools are located above the 21,000 cfs flow level; larvae and any remaining eggs still present during spring release peak flows would only infrequently be exposed to Colorado River flows. Average temperatures at Lees

Ferry under the No Action Alternative may be at or above 15°C (59°F) for the reservoir elevation at the 10th percentile in July, August, September and October (Table P-BCR-1). At the 50th and 90th percentiles, the average Lees Ferry temperatures are expected to remain predominantly below 15°C (59°F) under the No Action Alternative (Table P-BCR-1). Thus, temperatures would continue to remain below ideal temperatures for leopard frog under the No Action Alternative for most of the time.

Birds. Special status birds in this reach include bald eagle, California condor, southwestern willow flycatcher, Clark's grebe, osprey, belted kingfisher, snowy egret, and American peregrine falcon. For the same reasons that California condor, osprey, belted kingfisher, and American peregrine falcon would be unaffected at Lake Powell, the proposed federal action would not impact these species in the river reach between Glen Canyon Dam and Lake Mead. Steep shorelines limit the establishment of significant marshes in this river reach. It is unlikely that Clark's grebe or snowy egret would be impacted in this reach. Accordingly, only bald eagle and southwestern willow flycatcher are discussed further for this reach.

Bald eagles in this area are primarily winter residents and they feed largely on fish, waterfowl and carrion. Bald eagles feed on trout in the Lees Ferry area, and historically often congregate at Nankoweap Creek. Less than ideal river temperatures for trout may occur in the future in some years; however, despite such potential adverse effects on trout in some years, it is anticipated that trout will remain a food source for bald eagles under the No Action Alternative. Potential increases in river temperatures under the No Action Alternative or action alternatives may result in an increase in the warmwater fish population which could serve as a supplemental food source for bald eagles. The roost or nest sites are not anticipated to be effected in the future under the No Action Alternative.

Southwestern willow flycatchers nest in riparian shrub habitats of saltcedar and willow downstream of Glen Canyon Dam. Reduced flows in the future under the No Action Alternative would tend to continue favoring the establishment of riparian shrub vegetation in this reach. These conditions would benefit southwestern willow flycatchers since they inhabit willow and saltcedar plant communities and have generally benefited from post-Glen Canyon Dam conditions. This trend would continue into the future.

Action Alternatives. Releases under the action alternatives will only deviate from those under the No Action Alternative during the interim period for this river reach. Though conditions causing potential impacts would cease after the interim period, effects on vegetation communities during the interim period may be observed beyond the interim period.

Plants. At the 90th percentile for June Glen Canyon Dam releases, the Reservoir Storage Alternative may have spill avoidance releases that would exceed those under the No Action Alternative. June releases are the highest for the year at the

90th percentile and were used to gage potential impacts to Grand Canyon primrose habitat (Figure P-BCR-11 in Appendix P). These higher releases have a greater potential to adversely impact beach habitat and thus Grand Canyon evening primrose. These high flows may approach 28,000 cfs during the interim period, which is still less than recent experimental releases that have exceeded 40,000 cfs, so the impacts should be negligible. Releases under the Basin States, Conservation Before Shortage, and Water Supply alternatives, and the Preferred Alternative, sometimes exceed those under the No Action Alternative at the 90th percentile, but typically in months that are not the annual high release months, and the releases remain relatively close to those under the No Action Alternative. Therefore, these four action alternatives are not expected to result in impacts to Grand Canyon evening primrose. There could potentially be a minor negative impact on Grand Canyon primrose under the Reservoir Storage Alternative due to occasional spill avoidance releases discussed above.

Invertebrates. Kanab ambersnail habitat is impacted when flows exceed 17,000 cfs. During the interim period, flows under the Basin States and Conservation Before Shortage alternatives, and the Preferred Alternative, may exceed the flows observed under the No Action Alternative and 17,000 cfs in April and May at the 90th percentile (Figures P-BCR-11 and P-BCR-12). There are only a few isolated years under the other two action alternatives when flows are above those under the No Action Alternative and 17,000 cfs in these months. July releases at the 90th percentile under the Basin States and Conservation Before Shortage alternatives, and the Preferred Alternative, would be above 17,000 cfs, but lower than under the No Action Alternative, therefore possibly inundating less Kanab ambersnail habitat in this month. Flows under the Basin States and Conservation Before Shortage alternatives, and the Preferred Alternative, could also be above those under the No Action Alternative and 17,000 cfs at the 50th percentile in August, thus inundating more Kanab ambersnail habitat (Figure P-BCR-15). There could be flows under the Water Supply Alternative at the 50th percentile that are higher than those under the No Action Alternative and above 17,000 cfs in August, though this is the only month where this may occur under the Water Supply Alternative, and most of the time flows would be similar to those under the No Action Alternative when above 17,000 cfs (Figure P-BCR-15). In June, occasional spill avoidance releases under the Reservoir Shortage Alternative up to 4,000 cfs above those under the No Action Alternative (approaching 27,000 cfs) would flood additional Kanab ambersnail habitat (Figure P-BCR-13). The Kanab ambersnail population at Vasey's Paradise survived and recovered from innumerable similar and higher flows during the pre-Glen Canyon Dam era, and has survived six flows in excess of 45,000 cfs during the post-Glen Canyon Dam era (1965, 1980, and 1983 through 1986). Flows above 17,000 cfs could be produced under the Reservoir Storage Alternative, exceeding the flows observed under the No Action Alternative in December.

At the 10th percentile, all action alternatives may have lower releases from Glen Canyon Dam in some months. Though it is not possible to accurately project under which months those releases would occur or how many months in a row this would occur, these lower releases would allow spring vegetation at Vasey's Paradise to develop lower down on the canyon. Ambersnails could move into this lower habitat if releases are lower for long enough for such habitat to develop. When releases rise again, this habitat would be inundated and could impact ambersnails. However, this type of impact also occurs under the No Action Alternative. Accordingly, these potential impacts are expected to be minor, and the population that occurs above the zone of fluctuating releases should not be impacted under the action alternatives. Reclamation has consulted with FWS (FWS 1995; FWS 2002; Department 2004) on the effects of Glen Canyon Dam operations on the Vasey's Paradise population.

When releases under the Reservoir Storage Alternative exceed those under the No Action Alternative and 20,000 cfs in June and December at the 90th percentile, the Reservoir Storage Alternative would have a greater potential for a negative impact on Niobrara ambersnail habitat. In the months of June through September, and December, when Glen Canyon Dam releases under the No Action Alternative and the action alternatives are above 20,000 cfs at the 90th percentile, the magnitude of releases under the Basin States, Conservation Before Shortage, and Water Supply alternatives, and the Preferred Alternative, are equal to or less than those under the No Action Alternative. Thus, there is the potential for a positive impact on Niobrara ambersnail habitat during those months.

Fish. Lake Powell releases would be altered under the action alternatives, thus affecting sediment transport, water temperatures, and the potential range of hourly flows. Sediment transport is directly related to river flow, and annual releases below 8.23 mafy (as under the No Action Alternative) would transport less sediment out of the Colorado River and into Lake Mead while higher releases would transport more sediment (Section 4.5, Table 4.5-9). Temperature of the water released from Lake Powell depends on the reservoir elevation and various other conditions, with potentially warmer water being released when reservoir elevations are lower. As described for the No Action Alternative, daily fluctuations in river flows occur throughout the year. The potential range of hourly flows would be reduced, but not eliminated, in some months when annual releases are lower than 8.23 maf, and the potential range would increase in some months when annual releases are higher than 8.23 maf. Water temperatures corresponding to reservoir elevations at the 90th percentile are the same or nearly the same under the action alternatives as under the No Action Alternative; thus, no impacts would occur relative to the No Action Alternative at higher Lake Powell elevations. Temperature impacts of Lake Powell releases when lake elevations are at the 10th and 50th percentiles are described below for the action alternatives.

Preferred Alternative. Annual Glen Canyon Dam releases under the Preferred Alternative could be less than 8.23 mafy, with an approximately 9.7 percent higher probability than those under the No Action Alternative (Section 4.3, Table 4.3-11), which would reduce the transport of sediment out of the river and into Lake Mead (Section 4.5). Releases above the minimum objective release of 8.23 mafy would occur with a nearly 17 percent higher probability under the Preferred Alternative than under the No Action Alternative. These higher releases would transport more sediment out of the river. The probability of releases above nine mafy (9.01 mafy to above 16 mafy) is very similar (differ by approximately 0.5 percent) to the No Action Alternative and thus the effect on sediment transport would also be very similar to the No Action Alternative (Table 4.3-11). The impacts of these changes in sediment transport on instream habitat suitability and quantity for native fish are unknown, though higher rates of sediment transport could reduce the amount of fine sediment within the channel over time.

Average water temperatures at Lees Ferry under the Preferred Alternative would be the same as under the No Action Alternative at the 10^{th} and 50^{th} percentiles, resulting in no impact (Table P-BCR-1). Near the Little Colorado River confluence, average water temperatures would be up to 1ºC (1.8°F) warmer at the 10^{th} percentile and range from 1ºC (1.8ºF) warmer to 2ºC (3.6ºF) colder than the 50^{th} percentile of reservoir elevations (Table P-BCR-2). At Diamond Creek, the average temperatures would be less than 1.5ºC (2.7ºF) warmer at the 10^{th} percentile and range from 1ºC (1.8ºF) warmer to 1ºC (1.8ºF) colder than the 50^{th} percentile of reservoir elevations (Table P-BCR-3). These small changes in water temperature would have little effect on native fish spawning, egg incubation, and growth. The warmer temperatures at the 10^{th} percentile would increase the length of time that suitable temperatures are present for spawning of native fish (humpback chub, flannelmouth sucker, and bluehead sucker) from near the Little Colorado River to Lake Mead river reach while the slightly lower temperatures from September through March at the 50^{th} percentile would decrease the spawning season and growth in October for the bluehead sucker near Diamond Creek. The cooler water temperatures would not affect spawning or growth of the humpback chub or flannelmouth sucker.

The warmer temperatures at the 10^{th} percentile could also increase growth of the native species and their food base organisms, which could provide a minor positive impact to special status fish. The preferred temperature for invertebrates described above would not be exceeded by the warmer temperatures at the 10^{th} percentile of reservoir elevations, although the preferred temperature for *Cladophora* could be exceeded for a longer time relative to those under the No Action Alternative. These extensions of warm temperatures could occur in early July and late September near the Little Colorado River confluence and in early June and early October near Diamond Creek. However, *Cladophora* should remain present despite the potential for temperatures above its preferred thermal range, and invertebrates may benefit from warmer temperatures overall. The predominance of *Cladophora* downstream of Glen Canyon Dam appears to be linked to water clarity; substantial effects on river clarity trends in the reach between Glen Canyon Dam and Lake Mead are not expected under the Preferred Alternative.

The small increase in water temperatures at the 10^{th} percentile under the Preferred Alternative relative to those under the No Action Alternative also could benefit the non-native fish species present in the Colorado River by allowing earlier reproduction and increased growth in those years when such temperature increases occur. Furthermore, the small increase in temperature in some years has a low potential to increase movement of nonnative species into the river from Lake Mead (e.g., striped and largemouth bass) and from tributaries that provide inflow to the river in the years that such temperature increases occur, as discussed for the No Action Alternative. Since many non-native fish prey on native fish, the potentially increased number or feeding activity of non-native fish could adversely impact the native fish in this reach. However, many species of non-native fish are already present in this reach and the infrequent, slightly warmer temperatures are unlikely to significantly increase their abundance or species composition in the long term. Passage of non-native fish from Lake Powell to the Colorado River in releases under low reservoir elevations would have a slightly higher probability of occurring at the 10th percentile under the Preferred Alternative as compared to the No Action Alternative because lake elevations would generally be up to 13 feet lower under the Preferred Alternative from about 2025 to 2060 (Figures P-WQA-6, P-BCR-1, and P-BCR-2). Only some of these fish would survive this passage, resulting in few additional fish in the river to interact with native fish, which could result in a minor negative impact to special status fish.

Warmer river temperatures could increase the potential for expansion of the Asian tapeworm and anchorworm in the mainstream Colorado River in years when Lake Powell elevations are at the 10th percentile level (Table P-BCR-3). Water temperatures could be above 20ºC (53.8°F) for the same three months as under the No Action Alternative near Diamond Creek in those years. The level of effect is unknown but expected to be negligible considering the low frequency of warmer water occurrences and the small increase in temperature that could occur under the Preferred Alternative. Glen Canyon Dam releases made when Lake Powell elevations are at the 50th percentile of elevations result in approximately the same to cooler downstream temperatures that are always below 20°C (53.8°F) (Table P-BCR-3).

Releases from Glen Canyon Dam of less than 8.23 mafy could also result in a reduction in the potential range of hourly flows in the Colorado River (Section 4.3, Tables 4.3-13 and 4.3-14). The reduction in this potential range at a release rate of 7.48 mafy could be as much as 1,000 to 2,000 cfs in April, and October through December. This level of reduction would be unlikely to occur under the No Action Alternative and would have about an eight percent chance of occurring under the Preferred Alternative (Section 4.3, Table 4.3-11). For release rates of nine mafy, the potential range of hourly flows could be 2,000 cfs greater in June and September, and this annual release volume would have a higher probability of occurring under the Preferred Alternative than under the No Action Alternative (Section 4.3, Tables 4.3-11, 4.3-13 and 4.3-14). Because the range of hourly flows would change and the probability of this level of annual release is higher than under the No Action Alternative, an increased range of flows could impact habitat conditions for native fish.

Basin States Alternative. The probability of annual Glen Canyon Dam releases above nine maf and below 8.23 maf would be essentially the same as described for the Preferred Alternative (Section 4.3, Table 4.3-11), and the alteration of sediment transport would be the same. Average water temperatures in the Colorado River at Lees Ferry under the Basin States Alternative would be up to 1.9ºC (3.4ºF) warmer from March through August and up to 1.1ºC (2ºF) colder from October through February than under the No Action Alternative at the 10th percentile (Table P-BCR-1). At the 50th percentile, the average water temperatures would be up to 0.8ºC (1.4ºF) warmer from March through October and up to 1.4ºC (2.7ºF) colder in January and February than under the No Action Alternative. Average water temperatures at the 90th percentile would be within 0.5ºC (0.9ºF) of those under the No Action Alternative. These small changes in water temperature would not affect bluehead sucker and flannelmouth sucker spawning, egg incubation, and growth (humpback chubs are not in this reach). Average water temperatures would be the same at the Little Colorado River confluence and Diamond Creek as under the Preferred Alternative, and the impacts would also be the same (Tables P-BCR-2 and P-BCR-3). The probability of annual releases less than 8.23 maf would be approximately the same under the Basin States Alternative as under the Preferred Alternative with negligible impacts on native fish habitat (Section 4.3, Table 4.3-11).

Conservation Before Shortage Alternative. The probability of annual Glen Canyon Dam releases above nine maf and below 8.23 maf would be essentially the same as described for the Preferred Alternative (Section 4.3, Table 4.3-11), and the alteration of sediment transport would be the same. Average water temperatures would be the same as under the Basin States Alternative, and thus, impacts would also be the same. The probability of annual releases less than 8.23 maf would be approximately the same under the Conservation Before Shortage Alternative as under the Preferred Alternative and the Basin States Alternative, with negligible impacts on native fish habitat.

Water Supply Alternative. Annual Glen Canyon Dam releases of less than 8.23 mafy could result approximately 9.5 percent more frequently under the Water Supply Alternative than under the No Action Alternative (Section 4.3, Table 4.3-11), similar to the Preferred Alternative. During those times, sediment transport out of the Colorado River and into Lake Mead would be reduced. Higher annual release rates (between 9.01 and greater than 16 mafy) could occur with a frequency of about 24 percent higher under the Water Supply Alternative than under the No Action Alternative. These higher releases would transport more sediment into Lake Mead. The effects of these changes in release rates on habitat suitability and quantity for native fish are unknown.

Under the Water Supply Alternative, the Colorado River could be up to 2ºC (3.6ºF) warmer than under the No Action Alternative at the 10th percentile of elevations in the river reach extending to Lake Mead (Tables P-BCR-1 through P-BCR-3). Temperature changes throughout the river at the 50th percentile would range from about 1ºC (1.8ºF) warmer to 2ºC (3.6ºF) colder as described for the Preferred

Alternative. These changes in temperature at the 50th percentile are about the same for those under the Preferred Alternative, and impacts to native fish would be the same as described for the Preferred Alternative. At Lees Ferry, suitable spawning and egg incubation temperatures at the 10th percentile could be present in July for humpback chub and in June for flannelmouth sucker. The bluehead sucker could spawn in August and September compared to no spawning under the No Action Alternative. Near the Little Colorado River confluence, all three species could spawn a month earlier plus a month later for the bluehead sucker. Near Diamond Creek, humpback chubs could spawn a month earlier (May) than under the No Action Alternative while the other two species could spawn a few weeks earlier.

Under the Water Supply Alternative, water temperatures may support growth of all three species for one to two months longer in the Glen Canyon Dam to Lake Mead river reach than under the No Action Alternative at the 10th percentile of reservoir elevations. The cooler water temperatures in the fall and winter at the 50th percentile of elevation releases would not impact growth of the humpback chub or flannelmouth sucker but would not support growth of bluehead sucker in October near Diamond Creek.

The warmer water temperatures under the Water Supply Alternative would also benefit existing populations of non-native, non-game warmwater species such as carp, fathead minnows, catfish, and red shiner. This could increase competition for resources or predation on the native species which would have a negative impact on the native species, thereby at least partially offsetting the benefits of the warmer temperatures on the native species. Increasing water temperatures by up to about 2ºC (3.6°F), primarily during the spring and summer, could benefit non-native species as described for the Preferred Alternative, but a long-term increase in their population size and species composition is unlikely to occur due to the small, infrequent temperature increases. There is also a greater probability of providing favorable conditions for the migration of the Asian tapeworm and anchorworm into the mainstream of the Colorado River under the Water Supply Alternative than under the No Action Alternative because the Water Supply Alternative results in the lowest Lake Powell elevations, and thereby potentially warmer Glen Canyon Dam release temperatures. Based on the temperature modeling, however, average monthly water temperatures above 20ºC (68°F) could occur only near Diamond Creek from late June through September. These temperatures would be less than 2ºC (3.6°F) warmer than under the No Action Alternative and the duration would be about one month longer. Thus, increased parasitism of native fish in the Colorado River would have a low probability of occurring.

The passage of non-native fish through Glen Canyon Dam may occur as the lake elevations drop, and the greatest potential for this to occur is under the Water Supply Alternative, which tends to have lake elevations that are considerably lower than under the No Action Alternative after 2015 (Section 4.6, Figure 4.6-1; Figures P-BCR-1 and P-BCR-2).

Reservoir Storage Alternative. Annual Glen Canyon Dam releases of less than 8.23 mafy could result approximately 17 percent more frequently under the Reservoir Storage Alternative than under the No Action Alternative (Section 4.3, Table 4.3-11). When releases are below 8.23 mafy, sediment transport out of the Colorado River and into Lake Mead would be reduced. The probability of releases higher than nine mafy is similar to the No Action Alternative but about 1.5 percent more likely (Section 4.3, Table 4.3-11). The lower release rates would remove less sediment from the river system in those years when they occur. The effects of reduced sediment transport on habitat suitability and quantity of native fish habitat is unknown.

Under the Reservoir Storage Alternative, average monthly water temperatures in the Colorado River would be up to 0.8 ºC (1.4 ºF) warmer in some months and up to 2.8 ºC (5.0 ºF) colder in some months at the 10^{th} and 50^{th} percentiles relative to the No Action Alternative. At the 10^{th} percentile, the water could be too cold for growth of the humpback chub and flannelmouth sucker at Lees Ferry (Table P-BCR-1), and the number of months with adequate growth temperatures for the bluehead sucker would be reduced by one month (July) compared to the No Action Alternative. Near the Little Colorado River confluence, water temperatures would be too cold for humpback chub spawning during July, the only month when water would be warm enough for spawning under the No Action Alternative (Table P-BCR-2). The flannelmouth sucker growing season would be about one month shorter as would the bluehead sucker spawning season. Changes in water temperature near Diamond Creek at the 10^{th} percentile would not affect spawning or growth of the humpback chub, flannelmouth sucker, or bluehead sucker (Table P-BCR-3). At the 50^{th} percentile, the changes in water temperature compared to the No Action Alternative would not affect spawning or the growing season of these three species at Lees Ferry or near the Little Colorado River confluence. Near Diamond Creek, however, bluehead sucker growing season would be reduced by about one month due to the colder temperatures in October.

Average monthly water temperatures would be colder beginning in June or July at the 10^{th} percentile and would generally be less than 0.5ºC (0.9 ºF) warmer in the spring and fall (except at Lees Ferry where temperatures would be colder) compared to the No Action Alternative. At the 50^{th} percentile, average monthly water temperatures would be up to 0.5 ºC (0.9ºF) warmer in the spring to early summer (three to four months) and colder in the other months under the Reservoir Storage Alternative relative to the No Action Alternative. Because consistently warmer temperatures would not occur under the Reservoir Storage Alternative, changes in warmwater non-native fish populations would not be expected to occur. The cooler summer temperatures would provide less favorable conditions for migration of Asian tapeworm and anchorworm the into mainstream Colorado River than under the No Action Alternative. Based on the temperature modeling, average monthly water temperatures above 20 ºC (68 ºF) could occur only near Diamond Creek in July under the Reservoir Storage Alternative.

There is also a low potential for non-native fish passage from Lake Powell under the Reservoir Storage Alternative because the lake elevations are generally higher than those under the No Action Alternative (Section 4.6, Figure 4.6-1; Figures P-BCR-1 and P-BCR-2). Reductions in the potential range of hourly flows would also occur as described for the Preferred Alternative, and these reductions could occur a little more frequently because reduced releases could occur more frequently under the Reservoir Storage Alternative.

Amphibians. Because leopard frogs preferentially select warmer water for breeding, as such, the occasional introduction of warmer water would presumably benefit them. Lake Powell releases and average temperatures at Lees Ferry at the 50th percentile of reservoir elevations would always be colder than 15°C (59°F) under the alternatives, so there would be no temperature impact to leopard frogs at the 50th percentile of Lake Powell elevation releases (Table P-BCR-1). Average Lees Ferry temperatures of 15°C (59°F) or above may result under the No Action Alternative and the action alternatives, except under the Reservoir Storage Alternative, starting in July at the 10th percentile of Lake Powell elevations and continuing through October, which would provide a thermal benefit from less thermal shock to eggs and larvae (Table P-BCR-1). Under the Reservoir Storage Alternative average water temperatures would not reach 15ºC (59°F) until July, a minor negative impact compared to the No Action Alternative. Following Atkinson (1996), it is possible that the warmer water would increase the rate of metamorphosis but result in a smaller size class of metamorphs.

Flows under the action alternatives may inundate the Lees Ferry leopard frog habitat from June through September at the 90th percentile of Glen Canyon Dam releases (Figures P-BCR-11 through P-BCR-15). During the interim period, these high releases may differ from those under the No Action Alternative. There are no differences relative to the No Action Alternative beyond the interim period at these higher-end releases. Occasional June spill avoidance releases under the Reservoir Storage Alternative, when above 21,000 cfs, may exceed the releases that occur under the No Action Alternative by up to 4,000 cfs (Figure P-BCR-11). Though these higher flows would presumably have a greater impact on the Lees Ferry leopard frog habitat, they would occur in years when flows under the No Action Alternative may also exceed 21,000 cfs, so the inundation impacts would be similar, though the habitat may be under deeper water than under the No Action Alternative. The Basin States, Conservation Before Shortage, and Water Supply alternatives, and the Preferred Alternative, may have lower flows at the 90th percentile in July and September, but still above 21,000 cfs, so the inundation impacts would be similar to those under the No Action Alternative, though the habitat may be under shallower water (Figures P-BCR-13 and P-BCR-15).

Birds. Bald eagles may be indirectly impacted by alterations to the trout fishery. At the 10th percentile, the greatest potential temperature related impact to the trout fishery would occur under the Water Supply Alternative (Table P-BCR-1). However, these potential temperature effects are mitigated by the trout’s ability to move to thermal refugia at different Colorado River stages and because warmer temperatures will only occur in some years. Accordingly, despite these potential occasional changes in temperature, population-level impacts to the Lees Ferry trout fishery are not anticipated as a result of the proposed federal action. Warmer river flow temperatures may affect trout in some years and may benefit warmwater fish which could provide an alternative food source for bald eagles. The levels of potential flow impacts to vegetation communities anticipated under some alternatives are not likely to cause a significant impact to bald eagles. Given their mobility, varied diet, and lack of impacts to roost or nest sites, none of the action alternatives would substantially impact bald eagles that inhabit areas downstream of Glen Canyon Dam.

Though higher flows, particularly under the Reservoir Storage Alternative in June (Figure P-BCR-11), may flood riparian habitats, these flows would not be expected to impact southwestern willow flycatcher populations. Nests are typically above the 45,000 cfs stage. Reclamation concluded that long term effects of the 42,000 to 45,000 cfs test flow in 2002 on southwestern willow flycatcher habitat are expected to be beneficial (Reclamation 2002b). Saltcedar are expected to withstand potential increased flows that may occur under the Reservoir Storage Alternative peaks in June. Flows under the Basin States, Conservation Before Shortage, and Water Supply alternatives, and the Preferred Alternative, are higher than flows under the No Action Alternative by up to a few thousand cfs in some months, though these higher flows would not inundate southwestern willow flycatcher nests. When flows under the action alternatives (all at least in some months) are lower than those under the No Action Alternative (typically at the 10th percentile), these flows would not be expected to kill saltcedar, which is what southwestern willow flycatcher typically nest in downstream of Glen Canyon Dam.

Under the Basin States, Conservation Before Shortage, and Water Supply alternatives, and the Preferred Alternative, releases at the 10th percentile would be lower from April through September (Figures P-BCR-9 through P-BCR-15), and under the Reservoir Storage Alternative, releases at the 10th percentile would be lower from June through September (Figures P-BCR-11 through P-BCR-15). These lower releases may reduce moist soil conditions below nesting sites, which is a preference of southwestern willow flycatcher. Lack of moist soil below nest sites may degrade the habitat for this species, at least temporarily. A lack of moist soil conditions is more likely under the action alternatives than under the No Action Alternative at the 10th percentile of monthly releases, because there could be an annual release less than 8.23 maf under the action alternatives under certain conditions. Releases at the 50th percentile under the action alternatives would be at or above those under the No Action Alternative during the southwestern willow flycatcher nesting season. Therefore, potential impacts to southwestern willow flycatcher are only expected to occur coincident with lower releases which may occur in a few years.

Table 4.8-4 displays impacts to special status species in the Glen Canyon Dam to Lake Mead reach under the action alternatives relative to the No Action Alternative.

Table 4.8-4
Glen Canyon Dam to Lake Mead Reach Special Status Species Impact Summary
Comparison of Action Alternatives to No Action Alternative

Species	Alternative	Impact	Rationale
Mammals	All action alternatives	No impact	Flow differences not expected to rise to the level of indirectly impacting special status mammals.
Grand Canyon evening primrose	Conservation Before Shortage, Basin States, Water Supply, Preferred Alternative	No impact	Similar to 90th percentile releases under the No Action Alternative.
	Reservoir Storage	Minor-negative	Higher 90th percentile releases than under the No Action Alternative may affect beach habitat more than the No Action Alternative. Interim period only. High flows still less than experimental releases.
Kanab ambersnail	All action alternatives	Minor-negative	90th percentile releases exceed the No Action Alternative and 17,000 cfs. Interim period only. High flows still less than past high flows from which Kanab ambersnail has recovered.
Niobrara ambersnail	Reservoir Storage	Minor-negative	90th percentile releases exceed the No Action Alternative and 20,000 cfs. Interim period only. High flows still less than past high flows.
	Conservation Before Shortage, Basin States, Water Supply, Preferred Alternative	Minor-positive	When above 20,000 cfs at the 90th percentile of releases, impacts under the action alternatives are equal or less than those under the No Action Alternative.
Humpback chub, bluehead sucker, flannelmouth sucker	Conservation Before Shortage, Basin States, Preferred Alternative	Minor-positive to negative No impact No impact	Release temperatures similar to or slightly higher than those under the No Action Alternative with warming a little earlier in the year, resulting in small benefit to native fish, non-native fish, and fish parasites. Slightly less sediment loss due to reduced annual releases in some years and greater loss in some years due to higher annual releases. Reduction in range of hourly flows in some months during reduced releases and increased range during higher releases.
	Reservoir Storage	Minor-negative No impact No impact	Release temperatures slightly higher to or lower than those under the No Action Alternative with warmer temperatures primarily in the spring to early summer and cooler temperatures the remainder of the year, resulting in a shorter growing season for native fish and no benefit to non-native fish and fish parasites. Slightly less sediment loss due to reduced annual releases in some years and greater loss in some years due to higher annual releases. Reduction in range of hourly flows in some months during reduced releases and increased range during higher releases.

Table 4.8-4
Glen Canyon Dam to Lake Mead Reach Special Status Species Impact Summary
Comparison of Action Alternatives to No Action Alternative

Species	Alternative	Impact	Rationale
	Water Supply	Minor-positive to negative No impact No impact	Release temperatures similar to or slightly higher than those under the No Action Alternative with warming a little earlier in the year, resulting in small benefit to native fish, non-native fish, and fish parasites. Slightly less sediment loss due to reduced annual releases in some years and greater loss in some years due to higher annual releases. Reduction in range of hourly flows in some months during reduced releases and increased range during higher releases.
Northern leopard frog	Conservation Before Shortage, Basin States, Water Supply, Preferred Alternative	No Impact	Average river temperatures higher than 15°C (59°F) at the 10th percentile of releases would occur in the same months as under the No Action Alternative. High flows would inundate Lees Ferry frog habitat, but the habitat is inundated also under the No Action Alternative.
	Reservoir Storage	Minor-negative	Average river temperatures higher than 15°C (59°F) at the 10th percentile of releases would occur one month later than under the No Action Alternative. High flows inundate Lees Ferry frog habitat; the habitat is inundated also under the No Action Alternative.
Bald eagle	All action alternatives	No impact	Substantial indirect impacts through impacts to food sources not anticipated. Wide ranging species with the varied diet. Impacts to roost or nest sites are not anticipated.
Southwestern willow flycatcher	All action alternatives	Minor-negative	Lower flows at the 10th percentile may impact southwestern willow flycatcher but not saltcedar. Lower flows at the 10th percentile may reduce moist soil conditions below nest sites and degrade habitat value. Occurs under all action alternatives at the 10th percentile of releases.

4.8.4.3 Lake Mead

No Action Alternative.

Birds. Lake Mead elevations may exhibit a slight downward trend into the future under the No Action Alternative (Figures P-BCR-3 and P-BCR-4). This trend would have effects on the riparian and marsh habitats at the inflow areas and on the special status bird species that utilize such habitats for breeding, roosting or foraging. The downward trend of Lake Mead elevations would increase the potential for dewatering and sediment delta headcutting, which would adversely affect riparian and marsh vegetation that has developed on the sediment deltas. This adverse effect on the sediment delta in turn has the greatest potential to adversely affect special status birds that utilize cottonwood-willow and marsh habitats such as bald eagle, southwestern willow flycatcher, yellow-billed cuckoo, long-eared owl, American kestrel, osprey, Cooper's hawk, American peregrine falcon, northern harrier, Clark's grebe, snowy egret, Yuma clapper rail, California black rail, American bittern, western least bittern, great egret, white-faced ibis, belted kingfisher, and American white pelican.

Mammals. Townsend's big-eared bat, pale Townsend's big-eared bat, occult little brown bat, spotted bat, Allen's big-eared bat, western red bat, Yuma myotis, western yellow bat, cave myotis, greater western mastiff bat, and small-footed myotis may utilize the riparian and marsh habitats at Lake Mead for foraging and roosting. These bat species utilize a variety of habitats for roosting, including dead trees, so potential vegetation effects should not substantially impact roosting opportunities for these bats. Substantial effects to insect food sources for special status bats are not expected because Lake Mead elevations will continue to experience annual fluctuations and the downward trend will be gradual over time. The Yuma hispid cotton rat or Colorado River cotton rat would not be impacted under the No Action Alternative as these species are found further south along the lower Colorado River.

Amphibians. Relict leopard frog populations at Lake Mead would not be affected under the No Action Alternative because the known populations are at springs located above the influence of Lake Mead's elevation fluctuations. Colorado River toads are not known to exist at Lake Mead. Special status amphibians at Lake Mead are not expected to be affected under the No Action Alternative.

Plants. Sticky buckwheat, Geyer's milkvetch and Las Vegas bear poppy all occur at the shorelines of Lake Mead. These species typically benefit from lower reservoir elevations that expose additional shoreline habitat. Lake Mead would continue to experience elevation fluctuations under the No Action Alternative, which would result in varied levels of exposed shoreline through the year. The general downward trend of Lake Mead elevations that may occur under the No Action Alternative would generally result in increased shoreline exposure which would benefit these species while this trend continues.

Invertebrates. MacNeill's sooty-winged skipper is not known to exist at Lake Mead and would thus not be affected under the No Action Alternative. Potential vegetated habitats below the full pool elevation of Lake Mead are ephemeral and change over time as the lake elevation fluctuates.

Fish. Under the No Action Alternative, special status fish would experience Lake Mead elevations less than 1,120 feet msl all year at the 50th and 10th percentiles. The 90th percentile of reservoir elevations is generally projected to be near or above 1,200 feet msl all year. Modeled Lake Mead elevations for end of February, March, April, July, and September are provided in Figures P-BCR-3 through P-BCR-7. Razorback sucker spawning is known to occur between elevations 1,120 feet msl and 1,150 feet msl from January through June, and as elevations have dropped within this range and exposed areas used for spawning in earlier years, the fish have moved their spawning to nearby suitable areas (Albrecht and Holden 2006). Based on the modeled reservoir elevations under the No Action Alternative, the preferred spawning sites would be out of the water over 50 percent of the time during the spawning season. Razorback sucker would have to move to suitable spawning habitat at lower reservoir elevations, where such habitat is available.

Action Alternatives. Lake Mead elevations will deviate from those under the No Action Alternative during the interim period and the post-interim period.

Birds. No impacts to riparian or marsh habitats are anticipated at Lake Mead under the Basin States and Conservation Before Shortage alternatives, and the Preferred Alternative, because Lake Mead elevations under these action alternatives trend close to those under the No Action Alternative. Therefore, special status bird species at Lake Mead would not be impacted under these action alternatives.

Minor negative impact to cottonwood-willow, saltcedar and marsh vegetation at Lake Mead inflow areas and sediment deltas would result under the Water Supply Alternative. These negative impacts would be caused by lower reservoir elevations, increased dewatering of sediment deltas, and delta erosion. However, depending on duration of the lower elevations, the impact may be offset by new vegetation growing on the newly exposed sediments. These impacts to vegetation would cause minor negative impact to those special status bird species that forage, breed or roost in cottonwood-willow, saltcedar and marsh habitats. Potentially impacted species include: southwestern willow flycatcher, Clark's grebe, snowy egret, Yuma clapper rail, yellow-billed cuckoo, California black rail, American bittern, western least bittern, great egret, white faced ibis, long-eared owl, American kestrel, osprey, northern harrier, Cooper's hawk, bald eagle, belted kingfisher, American peregrine falcon, and American white pelican.

Minor positive impact to vegetation at Lake Mead would result under the Reservoir Storage Alternative, primarily at the inflow areas and sediment deltas. These positive impacts would be caused by higher reservoir elevations than under the No Action Alternative, and thus result in less potential for dewatering or sediment delta headcutting than under the No Action Alternative. Positive impacts are anticipated for the southwestern willow flycatcher, Clark's grebe, snowy egret, Yuma clapper rail, yellow-billed cuckoo, California black rail, American bittern, western least bittern, great egret, white faced ibis, long-eared owl, American kestrel, osprey, northern harrier, Cooper's hawk, bald eagle, belted kingfisher, American peregrine falcon, and American white pelican.

Mammals. Impacts to special status mammals at Lake Mead are not expected to occur for the same reasons provided for the No Action Alternative discussion.

Amphibians. Impacts to special status amphibians at Lake Mead are not expected for the reasons described for the No Action Alternative.

Plants. Sticky buckwheat, Geyer's milkvetch and Las Vegas bear poppy all occur at the shorelines of Lake Mead. These species typically benefit from lower reservoir elevations that expose additional shoreline habitat. These species would not be impacted under the Basin States and Conservation Before Shortage alternatives, and the Preferred Alternative, since reservoir elevations trend close to the elevations under the No Action Alternative. A minor beneficial impact would be provided to these species under the Water Supply Alternative through lowered elevations.

A minor negative impact to these species would be caused under the Reservoir Storage Alternative through raised elevations and inundation of shoreline habitats.

Invertebrates. MacNeill's sooty winged skipper is not known at Lake Mead, and would thus not be impacted under any action alternative. Habitats below the full pool elevation of Lake Mead are ephemeral and are periodically inundated and desiccated as the reservoir elevation changes.

Fish. Effects on razorback sucker spawning is the primary issue to be addressed for the alternatives. Since their spawning season is from January through June, modeling results for February, March, and April were used in the analysis. Lowered reservoir elevations are known to allow vegetation to grow on the exposed lake bed, and these areas are then inundated at higher reservoir elevations. These submerged vegetated areas can provide cover for juvenile razorback suckers and enhance their survival. Thus, periodic lower reservoir elevations may have some benefits (minor positive impact) to razorback sucker spawning success and recruitment after the reservoir elevations rise and inundate the vegetation growing on the edge under all alternatives. In addition, reservoir elevations would be nearly the same under all alternatives at the 90th percentile, resulting in no impacts relative to the No Action Alternative.

Preferred Alternative. Lake Mead elevations at the 50th percentile would be above those under the No Action Alternative through 2026 and then below until 2038 when the elevations become the same as those under the No Action Alternative (Figures P-BCR-3, P-BCR-4 and P-BCR-5). The maximum elevation would be 1,122 feet msl in February and the minimum would be 1,090 feet msl in April. Reservoir elevations may vary from 25 feet above to 13 feet below those under the No Action Alternative. The Preferred Alternative would have minor positive impacts when elevations are above those under the No Action Alternative (to 2026) to minor negative impacts when elevations are below those under the No Action Alternative. Reservoir elevations at the 10th percentile would vary from a little above to a little below those under the No Action Alternative until 2017 when the elevations would be above those under the No Action Alternative until after 2035. Because the elevations would be below the current elevations used by razorback suckers for spawning, no impacts would likely occur.

Reservoir elevations below those under the No Action Alternative would extend the riverine habitat where the Colorado River enters Lake Mead, which in turn would increase habitat for the humpback chub, razorback sucker, flannelmouth sucker, and bluehead sucker that could move downstream from Grand Canyon. At the 50th percentile of reservoir elevations, this minor benefit would occur from about 2026 through 2037, and at the 10th percentile this minor benefit would occur only in one to two years and thus would provide no benefit to those species.

Basin States Alternative. Under the Basin States Alternative, reservoir elevations may vary from ten feet above to ten feet below at the 50th percentile of reservoir elevations as compared to the No Action Alternative in February (Figure P-BCR-3), the month with the highest reservoir elevations. The maximum elevation may be 1,122 feet msl and the minimum 1,093 feet msl. In April, the maximum elevation may be 1,118 feet msl and the minimum 1,093 feet msl (Figure P-BCR-5). Minor positive impacts could occur under the Basin States Alternative when elevations are above those under the No Action Alternative (before 2020), to minor negative impacts when elevations are below those under the No Action Alternative (after about 2020). These impacts would trend to no impact. Reservoir elevations at the 10th percentile would be less than under the No Action Alternative until 2018 and then higher until 2033. Because the projected elevations would be below the current elevations used by razorback suckers for spawning, no impacts would likely occur.

There would be elevations at the 50th percentile under the Basin States Alternative above or only slightly below those under the No Action Alternative which would provide essentially no benefit to species in the Colorado River inflow. At the 10th percentile of reservoir elevations, there could be a minor positive impact prior to 2018 under this alternative.

Conservation Before Shortage Alternative. This alternative would be essentially the same as the Basin States Alternative at the 50th percentile of reservoir elevations with maximum and minimum elevations differing by one foot (Figures P-BCR-3, P-BCR-4, and P-BCR-5). At the 10th percentile of reservoir elevations, the Conservation Before Shortage Alternative would be similar to the Basin States Alternative in most years but not as high as, or above the No Action Alternative in 2021 through 2025.

Water Supply Alternative. Reservoir elevations at the 50th percentile under the Water Supply Alternative would be near or below those under the No Action Alternative until 2045 when they would become slightly higher, resulting in a minor negative impact compared to the No Action Alternative (Figures P-BCR-3, P-BCR-4, and P-BCR-5). At the 10th percentile, elevations under the Water Supply Alternative would be below and then above those under the No Action Alternative elevations, with no impact.

At the 50th percentile of reservoir elevations, the Water Supply Alternative would provide the greatest benefit, relative to the No Action Alternative, of any of the action alternatives to those species using riverine habitat at the Colorado River inflow to the reservoir, resulting in a minor positive impact.

Reservoir Storage Alternative. Under the Reservoir Storage Alternative, reservoir elevations at the 50th percentile would be above those under the No Action Alternative by up to 35 feet with occurrences of elevations above 1,125 feet msl from 2020 through 2037 with the maximum elevation at 1,135 feet msl (Figures P-BCR-3, P-BCR-4, and P-BCR-5). Thus, the Reservoir Storage Alternative would maintain reservoir elevations within the range currently used by razorback suckers for spawning more than 50 percent of the time in about half of the years modeled, a moderate positive impact. Reservoir elevations at the 10th percentile under the

Reservoir Storage Alternative would be above those under the No Action Alternative but none would be near the current elevations used for razorback spawning. Impacts could range from no effect to a minor positive impact but would likely result in no impact.

The Reservoir Storage Alternative would provide no riverine habitat increase relative to the No Action Alternative, a minor negative impact.

Table 4.8-5 compares potential special status species impacts under the action alternatives at Lake Mead relative to the No Action Alternative.

4.8.4.4 Hoover Dam to Davis Dam and Lake Havasu to Parker Dam

Due to lack of differences among the alternatives in these reaches, and the lack of change in vegetation or habitat, there would be no impacts to special status species at these locations.

4.8.4.5 Davis Dam to Lake Havasu

No Action Alternative. Monthly releases from Davis Dam exhibit a downward trend in the future at the 90th percentile (Figures P-BCR-32 through P-BCR-43). While special status species along the Colorado River are constantly making minor adjustments as flows fluctuate, downward trending releases could result in special status species habitat impacts.

Birds. Downward trending Davis Dam releases in the future under the No Action Alternative may have gradual adverse effects on cottonwood-willow and marsh habitats, which are utilized by many special status bird species. These species include: bald eagle, osprey, belted kingfisher, peregrine falcon, southwestern willow flycatcher, vermillion flycatcher, Clark's grebe, snowy egret, Yuma clapper rail, western yellow-billed cuckoo, California black rail, elf owl, gilded flicker, Gila woodpecker, Arizona Bell's vireo, Sonoran yellow warbler, summer tanager, American white pelican, double crested cormorant, American least bittern, Western bittern, great egret, black-crowned night heron, white faced ibis, black tern, long-eared owl, brown crested flycatcher, Lucy's warbler, yellow-breasted chat, northern cardinal, northern harrier, Cooper's hawk, and American kestrel. Since lower flows are more likely to affect cottonwood-willow than saltcedar, continued saltcedar expansion along the lower Colorado River is expected to be favored under the No Action Alternative.

Table 4.8-5
Lake Mead Special Status Species Impact Summary
Comparison of Action Alternatives to No Action Alternative

Species	Alternative	Impact	Rationale
Birds	Conservation Before Shortage, Basin States, Preferred Alternative	No impact	Reservoir elevations trend close to the No Action Alternative.
	Reservoir Storage	Minor-positive	Reservoir elevations trend higher than the No Action Alternative.
	Water Supply	Minor-negative	Reservoir elevations trend lower than the No Action Alternative.
Mammals	All action alternatives	No Impact	Substantial impacts to insect food sources for bats not anticipated.
Relict leopard frog	All action alternatives	No impact	Overton Arm population is located at a spring above Lake Mead's influence.
MacNeill's sooty-winged skipper	All action alternatives	No impact	Species not known at Lake Mead. LCR MSCP indicates zero acres of *atriplex* habitat at Lake Mead. Habitats below the full pool elevation are ephemeral under all alternatives.
Sticky buckwheat, Geyer's milkvetch, and Las Vegas bearpoppy	Conservation Before Shortage, Basin States, Preferred Alternative	No impact	Reservoir elevations trend close to the No Action Alternative.
	Reservoir Storage	Minor-negative	Reservoir elevations trend higher than the No Action Alternative, inundating shoreline habitat. Habitats below full pool elevation considered temporary due to reservoir, elevation fluctuation.
	Water Supply	Minor-positive	Reservoir elevations trend lower than the No Action Alternative, exposing additional shoreline habitat. Habitats below full pool elevation considered temporary due to reservoir elevation fluctuation.
Fish	Preferred Alternative	Minor-positive No impact Minor-positive	Elevations would be higher than the No Action Alternative in some years but seldom above the current razorback spawning areas at the 50th percentile of reservoir elevations. Elevations at the 10th percentile would be well below current razorback spawning areas. Lower elevations would extend riverine habitat at the inflow areas for species status fish at the 50th percentile of reservoir elevations.
	Conservation Before Shortage, Basin States	No impact Minor-positive	Elevations above 1,120 feet msl could have a slight benefit to razorback sucker spawning while lower elevations could be less valuable; at the 10th percentile, elevations under these alternatives would be above and below those under the No Action Alternative and below the current razorback spawning level. Increased amount of riverine habitat at the 10th percentile of reservoir elevations prior to 2018.
	Water Supply	Minor negative Minor positive	Reservoir elevations would be near to or less than those under the No Action Alternative at the 50th percentile of reservoir elevations. Lower reservoir elevations would provide more riverine habitat for fish from Separation Canyon at the 50th percentile of reservoir elevations.
	Reservoir Storage	Moderate positive Minor negative	Reservoir elevations would be above 1,120 feet msl over 50 percent of the time in about half the modeled years; at the 10th percentile of elevations, no impact. Higher reservoir elevations would provide less riverine habitat for fish from Separation Canyon than under the No Action Alternative at the 10th and 50th percentiles of reservoir elevations.

Mammals. Townsend's big-eared bat, Pale Townsend's big-eared bat, spotted bat, Allen's big-eared bat, Western red bat, occult little brown bat, Yuma myotis, Western Yellow bat, cave myotis, greater western mastiff bat, and small-footed myotis utilize riparian and marsh habitats in this reach for foraging and roosting. Downward trending Davis Dam releases under the No Action Alternative are expected to be gradual, though they may affect the composition of riparian habitats. Such gradual changes are not expected to substantially affect insect food sources for special status bats. Since these bats typically utilize a variety of roost sites, including live and dead trees, substantial impacts to these species' roost sites are not anticipated under the No Action Alternative.

The Yuma hispid cotton rat is only known to exist from Yuma south. This species will not be affected under the No Action Alternative in this reach. The Colorado River cotton rat inhabits this reach, and particularly grassy riparian areas along the Colorado River. Downward trending Davis Dam releases under the No Action Alternative are expected to be gradual, though they may impact the habitat for the Colorado River cotton rat in this reach. The lower monthly releases and lower annual median releases from Davis Dam under the Reservoir Storage Alternative could have a minor negative impact on the Colorado River cotton rat. The higher monthly and annual median releases from Davis Dam under the Water Supply Alternative could have minor positive impact on the Colorado River cotton rat. Monthly and annual median releases from Davis Dam under the Basin States and Conservation Before Shortage alternatives, and the Preferred Alternative, are similar to those under the No Action Alternative and therefore should not impact the Colorado River cotton rat.

Amphibians. Relict leopard frogs are known downstream of Hoover Dam at several springs to the north of this reach and are above the influence of the Colorado River. The Lowland leopard frog is known along the Bill Williams River, but not in this reach. The Colorado River toad is not known to occur in this reach. The special status amphibians in this reach would not be affected under the No Action Alternative.

Invertebrates. MacNeill's sooty-winged skipper is known at scattered sites along the lower Colorado River and is associated with quailbrush (*Atriplex*) and mesquite communities. The *Atriplex* land cover type is present in this reach (Section 3.8, Table 3.8-2). However, quailbrush typically grows on alluvial floodplains and flow-related impacts under the No Action Alternative are not anticipated to affect alluvial floodplains. Downward trending releases may affect groundwater levels. However, because the declines will likely be gradual and that mesquite and quailbrush are not obligate phreatophytes, groundwater-related effects under No Action Alternative are not anticipated. MacNeill's sooty-winged skipper in this reach is not expected to be affected under the No Action Alternative.

Fish. In the Colorado River reach between Davis Dam and Lake Havasu, some backwaters are present that could be used by razorback suckers, bonytail, and flannelmouth suckers, the only special status fish species present. Reduced flows in the future in this reach may result in more frequent dewatering of backwaters, resulting in a reduction of habitat for these special status fish species. Backwaters may become vegetated with marsh plants under reduced flow conditions. Non-native fish would continue to be present in this reach and compete with native fish.

Action Alternatives. Special status species in this reach would not be impacted under the Basin States and Conservation Before Shortage alternatives, and the Preferred Alternative, because Davis Dam monthly and annual median releases trend close to those under the No Action Alternative (Section 4.3, Figure 4.3-32; Figures P-BCR-32 through P-BCR-43), therefore, these three action alternatives are not discussed further for this reach. Flow deviations under the Water Supply and Reservoir Storage alternatives from those under the No Action Alternative generally return to those under the No Action Alternative at the end of the interim period, though the vegetation and associated special status species effects of interim period conditions may be observed beyond the interim period.

Birds. The Reservoir Storage and Water Supply alternatives may result in lower and higher monthly and annual median releases, respectively. Lower and higher annual median releases would have corresponding effects on groundwater levels and could impact riparian and marsh vegetation (Section 4.8). Respective impacts to special status birds would be similar to impacts at Lake Mead. However, a higher number of species may be impacted in this river reach since this reach includes California special status birds not considered at Lake Mead. There would be a minor negative impact on the following special status birds under the Reservoir Storage Alternative through flow-related and groundwater-related negative impacts to their habitats: bald eagle, osprey, belted kingfisher, peregrine falcon, southwestern willow flycatcher, vermillion flycatcher, Clark's grebe, snowy egret, Yuma clapper rail, western yellow-billed cuckoo, California black rail, elf owl, gilded flicker, Gila woodpecker, Arizona Bell's vireo, Sonoran yellow warbler, summer tanager, American white pelican, double crested cormorant, American least bittern, Western bittern, great egret, black-crowned night heron, white faced ibis, black tern, long-eared owl, brown crested flycatcher, Lucy's yellow warbler, yellow-breasted chat, northern cardinal, northern harrier, Cooper's hawk, and American kestrel. The Water Supply Alternative is expected to have a minor positive impact on these same species since monthly and annual median flows will be higher than under the No Action Alternative. Fluctuations of groundwater levels anticipated for this reach may be on the order of 0.5 foot or less (Section 4.3), which contributes to these impacts being minor.

Mammals. Though there may be higher and lower Davis Dam releases under the Water Supply and Reservoir Storage alternatives, respectively, these differences are not expected to substantially impact foraging or roosting conditions for special status bats. Impacts under the action alternatives on special status mammals are expected to be similar to those expected under the No Action Alternative.

The Yuma hispid cotton rat is only known to exist along the Colorado River from Yuma south. Therefore, the proposed federal action would not impact this species in this reach. The Colorado River cotton rat is present in this reach and its habitat could be adversely impacted by the lower monthly and annual median releases from Davis Dam and potentially lower groundwater levels associated with the Reservoir Storage Alternative. The Water Supply Alternative could have a small positive impact on this species' habitat because the higher monthly and annual median releases from Davis Dam under this alternative would benefit riparian and marsh vegetation in this reach.

Amphibians. There would be no impacts under the Water Supply and Reservoir Storage alternatives to the Colorado River toad, relict leopard frog or lowland leopard frog in this reach for the same reasons as described for the No Action Alternative.

Invertebrates. There would be no impacts under the Water Supply and Reservoir Storage alternatives to MacNeill's sooty-winged skipper in this reach for the same reasons as described for the No Action Alternative.

Fish.

Water Supply Alternative. There may be slightly more flows under the Water Supply Alternative than under the No Action Alternative in most months of the year at the 10^{th} and 50^{th} percentiles of reservoir elevations. The slightly higher flows could have a minor positive impact on the razorback sucker, bonytail, and flannelmouth sucker.

Reservoir Storage Alternative. There may be slightly lower flows under the Reservoir Storage Alternative than under the No action Alternative in most months of the year at the 10^{th} and 50^{th} percentiles of reservoir elevations. Reductions in Colorado River flows downstream of Davis Dam could affect the flannelmouth sucker through loss of spawning habitat in the riverine sections and rearing habitat in backwaters. This would be a minor negative impact for this species. Reduced flows could also have a minor negative impact on razorback sucker and bonytail through loss of rearing habitat. At the 90^{th} percentile, higher releases in the winter under the Reservoir Storage Alternative could have potential benefits or detriments to backwater habitats depending on the amount of sediment scour or deposition. Overall, however, no impact would be expected from higher winter releases.

Table 4.8-6 provides a summary of potential impacts that may occur under the action alternatives to special status species in the Davis Dam to Lake Havasu reach as compared to the No Action Alternative.

Table 4.8-6
Davis Dam to Lake Havasu Reach Special Status Species Impact Summary
Comparison of Action Alternatives to No Action Alternative

Species	Alternative	Impact	Rationale
Birds	Conservation Before Shortage, Basin States, Preferred Alternative	No Impact	Monthly and annual median releases are similar to the No Action Alternative.
	Water Supply	Minor-positive	Monthly and annual median releases higher than under the No Action Alternative at the 10th and 50th percentiles.
	Reservoir Storage	Minor-negative	Monthly and annual median releases lower than under the No Action Alternative at the 10th and 50th percentiles.
Mammals	Conservation Before Shortage, Basin States, Preferred Alternative	No impact	Conservation Before Shortage and Basin States alternatives monthly and annual median releases are similar to those under the No Action Alternative.
	Reservoir Storage	Minor-negative	Lower monthly and annual median releases from Davis Dam could degrade riparian habitats of the Colorado cotton rat. Flow differences not expected to impact special status bats.
	Water Supply	Minor – positive	Higher monthly and annual median releases from Davis Dam could benefit riparian habitats of the Colorado River cotton rat. Flow differences not expected to impact special status bats.
Amphibians	All action alternatives	No Impact	Species not known in this reach.
Invertebrates	All action alternatives	No impact	Action alternatives not expected to adversely impact quailbrush or mesquite communities on alluvial floodplains.
Fish	Conservation Before Shortage, Basin States, Preferred Alternative	No impact	Davis Dam releases trend close to those under the No Action Alternative.
	Water Supply	Minor- positive	Increased releases at the 10th and 50th percentiles of reservoir elevations could benefit razorback sucker, bonytail, and flannelmouth sucker.
	Reservoir Storage	Minor- negative	Decreased releases at the 10th and 50th percentiles of reservoir elevations could result in habitat reduction for razorback sucker, bonytail, and flannelmouth sucker.

4.8.4.6 Parker Dam to NIB

No Action Alternative. Monthly flows from Parker Dam to Imperial Dam may be sightly lower in future years because of a reduction in the 90th percentile releases in some months (Figures P-BCR-44 through P-BCR-55). Annual median releases from Parker Dam also indicate a slight downward trend into the future (Section 4.3, Figure 4.3-37). While special status species along the Colorado River are constantly adjusting as flows fluctuate, the slight downward trend in the future could adversely affect cottonwood and marsh communities and the special status species that rely on such habitats. Under the No Action Alternative, shortage conditions would occur without specific operating criteria.

The gradual nature of this slight downward trend is such that terrestrial special status species and habitat conditions would not change abruptly or substantially. The Colorado River downstream of Imperial Dam would not be affected under the No Action Alternative because flows between Imperial Dam and the NIB consist primarily of leakage from Imperial Dam and return flows from water diverted at Imperial Dam. Accordingly, there will be no effects under the proposed federal action on special status species downstream of Imperial Dam. The following discussion applies only to the Colorado River reach between Parker Dam and Imperial Dam.

Birds. The gradual and slight downward trend of monthly and annual median flows in this reach in the future may adversely affect cottonwood-willow and marsh habitats and thus the special status birds that utilize such habitats. These species include: bald eagle, osprey, belted kingfisher, peregrine falcon, southwestern willow flycatcher, vermillion flycatcher, Clark’s grebe, snowy egret, Yuma clapper rail, western yellow-billed cuckoo, California black rail, elf owl, gilded flicker, Gila woodpecker, Arizona Bell’s vireo, Sonoran yellow warbler, summer tanager, American white pelican, double crested cormorant, American bittern, Western least bittern, great egret, black-crowned night heron, white faced ibis, black tern, long-eared owl, brown crested flycatcher, Lucy’s warbler, yellow-breasted chat, northern cardinal, northern harrier, Cooper’s hawk, and American kestrel. Lower flows would continue to favor expansion of saltcedar along this reach, which tends to reduce the value of the habitats the species invades.

Mammals. The gradual and slight downward trend of monthly and annual median flows in this reach in the future under the No Action Alternative would have similar effects on special status bats as described for the No Action Alternative for the Davis Dam to Lake Havasu reach.

The Yuma hispid cotton rat and Colorado River cotton rat do occur in this reach and they inhabit moist grassy areas along the lower Colorado River, including wetlands. The downward trend of monthly and annual median releases from Parker Dam under the No Action Alternative may have minor effects on the moist riparian habitats these two species prefer. However, since these species also utilize agricultural fields and the downward release trend is gradual and small, effects under the No Action Alternative on these two rat species is expected to be small.

Amphibians. Special status amphibians do not occur in this reach, thus, effects under the No Action Alternative are not anticipated.

Invertebrates. MacNeill's sooty-winged skipper may occur in the quailbrush and mesquite communities that are present in this reach. However, the alluvial floodplains or *Atriplex* communities are not expected to be affected or impacted under the No Action Alternative through groundwater effects. MacNeill's sooty-winged skipper in this reach would not be affected under the No Action Alternative.

Fish. The only listed fish species present in the Colorado River or in-stream reservoirs from Parker Dam to the NIB are the razorback sucker and bonytail chub. Reduced flows under the No Action Alternative would alter habitat for these fish downstream of Parker Dam as described for downstream of Davis Dam.

Action Alternatives. Flow deviations under the action alternatives from those under the No Action Alternative generally return close to those under the No Action Alternative at the end of the interim period, though the vegetation and associated special status species effects of the interim period may be observed beyond the interim period.

Birds. In the river reach between Parker Dam and Imperial Dam, monthly and annual median flows under the Basin States, Conservation Before Shortage, and Reservoir Storage alternatives, and the Preferred Alternative, would be lower than under the No Action Alternative at the 10th and 50th percentiles. The Reservoir Storage Alternative results in the greatest reduction of flows as compared to the No Action Alternative, while the Basin States Alternative results in the least reduction (Section 4.3, Figure 4.3-37; Figures P-BCR-44 through P-BCR-55). Departures under the action alternatives from the No Action Alternative may cause a decline in groundwater levels adjacent to the Colorado River of 0.15 to 0.30 foot. These lower releases and groundwater levels would have a minor negative impact on cottonwood-willow and marsh habitats and thus a correspondingly minor negative impact to special status birds that rely on those habitats. Potentially impacted species include the following: bald eagle, osprey, belted kingfisher, peregrine falcon, southwestern willow flycatcher, vermillion flycatcher, Clark's grebe, snowy egret, Yuma clapper rail, western yellow-billed cuckoo, California black rail, elf owl, gilded flicker, Gila woodpecker, Arizona Bell's vireo, Sonoran yellow warbler, summer tanager, American white pelican, double crested cormorant, American bittern, Western least bittern, great egret, black-crowned night heron, white faced ibis, black tern, long-eared owl, brown crested flycatcher, Lucy's yellow warbler, yellow-breasted chat, northern cardinal, northern harrier, Cooper's hawk, and American kestrel. The annual median flows under the Water Supply Alternative are somewhat higher than under No Action Alternative and therefore would have a minor positive impact on cottonwood-willow and marsh habitats, and on these same special status species.

Mammals. The special status bat species would not be impacted in this reach for the same reasons as described for the Davis Dam to Lake Havasu reach.

The lower flows, declines in groundwater levels adjacent to the river of 0.15 to 0.30 foot, and resultant impacts to riparian vegetation associated with the Basin States, Conservation Before Shortage, and Reservoir Storage alternatives, and the Preferred Alternative, could have a minor negative impact on the Colorado River cotton rat upstream of Imperial Dam. The higher flows, groundwater levels, and small positive impacts to riparian vegetation under the Water Supply Alternative could have a minor positive impact on the Colorado River cotton rat upstream of Imperial Dam. The action alternatives would not alter the historic operational methodology or range of flow volumes in the river channel downstream of Imperial Dam. Therefore, none of the action alternatives would impact the Yuma hispid cotton rat or Colorado River cotton rat downstream of Imperial Dam.

Amphibians. Special status amphibians do not occur in this reach.

Invertebrates. MacNeill's sooty-winged skipper would not be impacted in this reach because alluvial floodplains with quailbrush and mesquite are not expected to be substantially impacted under any alternative.

Fish. The Basin States, Conservation Before Shortage, and Reservoir Storage alternatives, and the Preferred Alternative, have monthly releases that would be less than those under the No Action Alternative at the 10^{th} and 50^{th} percentiles. These lower flows could have impacts on razorback sucker and bonytail chub similar to those described for the Reservoir Storage Alternative in the Davis Dam to Lake Havasu reach. The use of High Levee Pond on the Cibola NWR for native fish would not be affected by changes in releases from Parker Dam.

Table 4.8-7 summarizes the potential impacts to special status species in the Parker Dam to the NIB reach for the action alternatives relative to the No Action Alternative.

Table 4.8-7
Parker Dam to NIB Special Status Species Impact Summary
Comparison of Action Alternatives to No Action Alternative

Species	Alternative	Impact	Rationale
Birds	Water Supply	Minor - Positive	Monthly releases closely follow the No Action Alternative. No flow-related impacts anticipated downstream of Imperial Dam. Annual median releases from Parker Dam are higher than under the No Action Alternative, which provides a minor benefit to riparian habitats and associated birds.
	Conservation Before Shortage, Basin States, Reservoir Storage, Preferred Alternative	Minor-negative	Monthly releases lower than under the No Action Alternative at the 10th and 50th percentiles. Small anticipated groundwater level impacts. No flow-related impacts anticipated downstream of Imperial Dam. Annual median releases from Parker Dam are lower than under the No Action Alternative, which results in a minor negative impact to riparian habitats and associated birds.
Mammals	Water Supply	Minor - Positive	Monthly flows under the Water Supply Alternative are similar to those under the No Action Alternative. Flows are not substantially different than those under No Action Alternative to cause indirect impacts to special status bats. Higher annual median releases from Parker Dam could benefit Colorado River cotton rat upstream of Imperial Dam. Two cotton rat species occur downstream of Imperial Dam, where flow impacts are not anticipated.
	Conservation Before Shortage, Basin States, Reservoir Storage, Preferred Alternative	Minor - Negative	Monthly flows are similar to those under the No Action Alternative. Flows are not substantially different than those under the No Action Alternative to cause indirect impacts to special status bats. Lower annual median releases from Parker Dam could benefit Colorado River cotton rat upstream of Imperial Dam. Two cotton rat species occur downstream of Imperial Dam, where flow impacts are not anticipated.
Amphibians	All action alternatives	No Impact	Species not known in this reach.
Invertebrates	All action alternatives	No impact	Action alternatives not expected to adversely impact quailbrush or mesquite communities on alluvial floodplains.
Razorback sucker and bonytail chub	Water Supply	No Impact	Monthly flows closely follow those under the No Action Alternative.
	Conservation Before Shortage, Basin States, Reservoir Storage, Preferred Alternative	Minor-negative	Monthly flows are lower than those under the No Action Alternative at the 10th and 50th percentiles and could result in habitat reduction.

4.8.4.7 NIB to SIB

No Action Alternative. The lack of flows precludes the presence of a significant river fishery in the Colorado River reach between Morelos Diversion Dam and the SIB (Limitrophe Division); the riparian and marsh habitats, and the special status species that rely on those habitats are adversely affected by this condition. Flows past Morelos Diversion Dam tend to benefit downstream vegetated habitats and associated special status species. The probability of these excess flows occurring in the future under the No Action Alternative is relatively low, typically less than 20 percent (Figure P-BCR-56). The infrequency of flows under the No Action Alternative would continue to maintain less than ideal conditions for cottonwood-willow and marsh habitats and the species that rely on such habitats. The special status bird and mammal species identified in the Parker Dam to the NIB reach will continue to experience these adverse effects on their habitat downstream of Morelos Diversion Dam under the No Action Alternative. Special status amphibians, plants or fish will not be affected under the No Action Alternative because none are present in this reach. Infrequent flows in this reach under the No Action Alternative will continue to favor the expansion of saltcedar which may compete with mesquite and quailbrush communities, thus limiting the habitat potential for MacNeill's sooty-winged skipper in this reach.

Action Alternatives. The likelihood of excess flows passing Morelos Diversion Dam under the Basin States and Water Supply alternatives, and the Preferred Alternative, is approximately the same as under the No Action Alternative. Therefore, these action alternatives would have no impact on special status species in this reach. The Reservoir Storage and Conservation Before Shortage alternatives have a higher likelihood of excess flows passing Morelos Diversion Dam than the No Action Alternative (Figure P-BCR-56). In addition, due to modeling assumptions for the Reservoir Storage and Conservation Before Shortage alternatives, water is assumed to be delivered to Mexico and assumed to allow to pass the Morelos Diversion Dam via periodic flows[2] of about 40 kafy to 200 kafy (Section 2.4). These pulse flows would occur approximately every other year during the interim period only. The probability of flows past Morelos Diversion Dam under these two action alternatives returns to the probability of flows under the No Action Alternative after the interim period. These flows would have overall benefits to river flow, riparian and marsh vegetation and special status species that utilize these habitats since substantial flow in this reach is relatively rare. There would be a moderate, positive impact on special status species between Morelos Diversion Dam and the SIB under the Reservoir Storage and Conservation Before Shortage alternatives.

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[2] These flows were modeled as part of the storage and delivery mechanism under the Conservation Before Shortage and Reservoir Storage alternatives. The modeling assumptions were utilized in this Final EIS in order to analyze the potential impacts to environmental resources of the storage and delivery mechanism, particularly with regard to reservoir elevations and river flow impacts. The use of these modeling assumptions does not represent any determination by Reclamation as to whether, or how, these releases could be made under current management of the Colorado River.

Birds. The species identified as impacted in the Parker Dam to the NIB reach would be positively impacted by the increased likelihood of flows past Morelos Diversion Dam under the Reservoir Storage and Conservation Before Shortage alternatives. Special status birds would not be impacted under the Basin States and Water Supply alternatives, and the Preferred Alternative, since under these action alternatives flows past Morelos Diversion Dam are just as likely to occur as under the No Action Alternative.

Amphibians, Plants and Fish. There are no special status amphibians, plants or fish in this reach.

Mammals. The increased likelihood of flows past Morelos Diversion Dam under the Reservoir Storage and Conservation Before Shortage alternatives would provide a moderate benefit to riparian and marsh habitats downstream of Morelos Diversion Dam, which would potentially benefit special status bats, the Yuma hispid cotton rat, and Colorado River cotton rat in this reach.

Invertebrates. The *Atriplex* land cover type is present in this reach, which may provide habitat for MacNeill's sooty-winged skipper. Though not specifically known in this reach, the species has been documented in Yuma County, Arizona. Flows past Morelos Diversion Dam under the Basin States and Water Supply alternatives, and the Preferred Alternative, are as likely to occur as under the No Action Alternative. Flows past Morelos Diversion Dam under the Reservoir Storage and Conservation Before Shortage alternatives are more likely to occur. Though an overall benefit to habitat conditions, flows past Morelos Diversion Dam could scour riparian vegetation, potentially including *Atriplex*, which serves as potential habitat for MacNeill's sooty-winged skipper. Thus, these alternatives would potentially have a minor negative impact on this species, despite overall benefits to the conditions in this reach.

Table 4.8-8 summarizes the impacts to special status species in the NIB to the SIB reach for the action alternatives relative to the No Action Alternative.

4.8.5 Summary

4.8.5.1 Vegetation and Wildlife

Lake Powell and Lake Mead. Under the Water Supply Alternative there may be a minor negative impact on obligate phreatophytes, and marsh and the wildlife that use such habitats because lake elevations tend to be lower than under the No Action Alternative. Under the Basin States, Conservation Before Shortage, and Reservoir Storage alternatives, and the Preferred Alternative, there may be a minor positive impact on obligate phreatophytes, and marsh and associated wildlife because lake elevations tend to be higher than under the No Action Alternative.

Table 4.8-8
NIB to SIB Reach Special Status Species Impact Summary
Comparison of Action Alternatives to No Action Alternative

Species	Alternative	Impact	Rationale
Birds	Basin States, Water Supply, Preferred Alternative	No Impact	Flows past Morelos Diversion Dam just as likely under the No Action Alternative.
	Reservoir Storage, Conservation Before Shortage	Moderate – positive	Flows past Morelos Diversion Dam more likely than under the No Action Alternative. Flows are rare in this reach, so increased likelihood would benefit the riparian corridor and associated special status species.
Mammals	Basin States, Water Supply, Preferred Alternative	No impact	Flows past Morelos Diversion Dam just as likely under the No Action Alternative.
	Reservoir Storage, Conservation Before Shortage	Moderate-positive	Flows past Morelos Diversion Dam more likely than under the No Action Alternative. Flows are rare in this reach, so increased likelihood would benefit the riparian corridor and associated special status species.
Amphibians, Plants and Fish	All action alternatives	No Impact	Fish occurrence is problematic due to lack of steady flows. No special status plants or amphibians are known in this reach.
MacNeill's sooty-winged skipper	Basin States, Water Supply, Preferred Alternative	No impact	Flows past Morelos Diversion Dam just as likely under the No Action Alternative.
	Reservoir Storage, Conservation Before Shortage	Minor-negative	*Atriplex* vegetation occurs in this reach and could be impacted by scouring by increased likelihood of flow past Morelos Diversion Dam.

Glen Canyon Dam to Lake Mead. All five action alternatives tend to have lower 10th percentile releases from Glen Canyon Dam than the No Action Alternative. These lowered releases may negatively impact obligate phreatophytes, and marsh and associated wildlife downstream of Lake Powell. The impacts are expected to be minor because though lower, they are within the range of recent history and are anticipated for the interim period only.

Hoover Dam to Davis Dam and Lake Havasu to Parker Dam. Under all five action alternatives there would be no impacts to vegetation or wildlife in these river reaches because there may be only small differences in Lake Mead releases and these reaches are dominated by Lake Mohave and its backwater, and Lake Havasu. Vegetated habitats potentially affected by flow changes between Hoover Dam and Lake Mohave are limited. Lake Mohave and Lake Havasu are operated on monthly rule curves so vegetation and wildlife effects at the lakes under the action alternatives are identical to those under the No Action Alternative.

Davis Dam to Parker Dam. Under the Water Supply Alternative there may be higher 10th and 50th percentile monthly releases and a higher annual median release from Davis Dam; this may cause a minor positive impact to obligate phreatophytes, and marsh and associated wildlife as compared to the No Action Alternative. Under the Reservoir Storage Alternative, there may be lower 10th and 50th percentile monthly releases and a lower annual median release from Davis Dam; this may cause a minor negative impact to obligate phreatophytes, and marsh and associated wildlife as compared to the No Action Alternative. These differences remain within the range of annual fluctuations that have historically occurred, and are expected to occur during the interim period only.

Parker Dam to Imperial Dam. Under the Basin States, Conservation Before Shortage, and Reservoir Storage alternatives, and the Preferred Alternative, there are lower 10th and 50th percentile monthly releases and a lower annual median release from Parker Dam; these lower releases may have a minor negative impact on obligate phreatophytes, and marsh and associated wildlife. Under the Water Supply Alternative there is a higher annual median release from Parker Dam, which may provide a minor benefit to obligate phreatophytes, and marsh and associated wildlife.

Imperial Dam to NIB. There are no impacts to vegetation or wildlife under any of the action alternatives in this reach. Flow changes in this reach would be limited to the AAC rather than to the Colorado River downstream of Imperial Dam. No impacts to vegetation or wildlife are anticipated from differences in flows within the AAC.

NIB to SIB. Mexico diverts its water at Morelos Diversion Dam (at the NIB) and flows downstream of this dam are rare. There is a higher probability of excess flows passing Morelos Diversion Dam under the Conservation Before Shortage and Reservoir Storage alternatives than under the No Action Alternative, which is expected to cause a moderate positive benefit to river flows, obligate phreatophytes, and marsh and associated wildlife downstream of Morelos Diversion Dam. These benefits were deemed moderate because flows in this reach are currently rare and any additional flow in this reach is assumed to be beneficial.

4.8.5.2 Special Status Species

Lake Powell. Lower Lake Powell elevations under the Basin States, Conservation Before Shortage, and Water Supply alternatives, and the Preferred Alternative, at the 10th and 50th percentile of reservoir elevations may increase the amount of riverine habitat available at the inflow areas to Lake Powell. This may provide a minor positive impact to razorback sucker, bonytail, Colorado pikeminnow, and flannelmouth sucker found in the riverine areas at the inflows. The higher lake elevations under the Reservoir Storage Alternative may decrease the amount of riverine habitat at the inflow areas, which may result in a minor negative impact.

Clark's grebe that may inhabit Lake Powell could be impacted by elevation changes in Lake Powell that affect marsh habitat at the inflow areas. Under the Reservoir Storage and Water Supply alternatives, there may be higher and lower lake elevations, respectively, which would mean a minor positive and a minor negative impact, respectively, to Clark's grebe.

Glen Canyon Dam to Lake Mead. Under the action alternatives, except for the Reservoir Storage Alternative, there may result higher river temperatures downstream of Glen Canyon Dam at the 10th percentile of elevations and higher to lower temperatures at the 50th percentile of elevations than under the No Action Alternative. Under the Reservoir Storage Alternative there may result higher to lower river temperatures at the 10th and 50th percentiles of elevations, respectively. Higher temperatures may provide a minor positive impact to humpback chub, bluehead sucker and flannelmouth sucker spawning and growth. However, these warmer temperatures also benefit non-native fish species which compete with native fish, and parasites that affect native fish, resulting in a minor negative impact. The lower average temperatures in the summer and winter at the 10th percentile of elevations under the Reservoir Storage Alternative could reduce the growing season for humpback chub, bluehead sucker, and flannelmouth sucker but would not affect spawning, resulting in a minor negative impact. The short duration of warmer average temperatures in the spring followed by cooler temperatures are unlikely to provide any benefit to non-native fish and native fish parasites. Lower annual releases in some years could reduce sediment loss from the Colorado River while higher releases in some years could increase sediment losses. How these changes in sediment transport could affect native fish habitat is unknown. The range in hourly flows could be reduced during lower annual releases and increased during higher annual releases. Lower temperatures may provide a minor negative impact to these native fish species. Under the Reservoir Storage Alternative, average water temperatures above 15ºC (59°F) may occur one month later than under the No Action Alternative and may have a minor negative impact on leopard frogs due to increased potential for thermal shock in July. Under the other action alternatives impacts to the leopard frog are not expected as compared to the No Action Alternative.

Higher 90th percentile releases under the Reservoir Storage Alternative have a potential for increased impact to beach habitat in the lower Grand Canyon, which could adversely impact vegetation and Grand Canyon evening primrose on those beaches. Under the five action alternatives, flows may exceed those under the No Action Alternative and 17,000 cfs in some months, which may cause additional impact to Kanab ambersnail habitat at Vasey's Paradise. Under the Reservoir Storage Alternative, flows in June could exceed those under the No Action Alternative and exceed 20,000 cfs, thus causing greater impact to Niobrara ambersnail habitat. Under the Basin States, Conservation Before Shortage, and Water Supply alternatives, and the Preferred Alternative at the 90th percentile there may be flows that when above 20,000 cfs are equal to or less than those under No Action Alternative, which would provide a minor positive benefit to the Niobrara ambersnail. Under the five action alternatives there may be a minor negative impact on the southwestern willow flycatcher because of the 10th percentile release flows trend lower than those under the No Action Alternative. These lower potential flows could adversely impact southwestern willow flycatcher habitat in the Grand Canyon.

Lake Mead. The lower and higher Lake Mead elevations that may occur under the Water Supply and Reservoir Storage alternatives, respectively, could cause minor negative and minor positive impacts, respectively, to special status bird species. Impacts on bird species may be caused by increased or decreased potential for dewatering of riparian habitats and headcutting at the Lake Mead inflow areas. Higher lake elevations under the Reservoir Storage Alternative may inundate additional shoreline habitat for the sticky buckwheat, Geyer's milkvetch and Las Vegas Bearpoppy and be a minor negative impact. Lower Lake Mead elevations under the Water Supply Alternative may expose additional shoreline habitat for these plants and be a minor positive impact. These impacts were deemed minor because all habitats below the full pool elevation of Lake Mead are subject to periodic inundation and exposure as the lake elevation fluctuates in the future. Under the Preferred Alternative, there could be minor positive impacts to special status fish when elevations are above the current razorback spawning areas at the 50^{th} percentile of elevations and when lower elevations would extend riverine habitat in the inflow area for special status fish. Elevations higher than under the No Action Alternative at the 10^{th} percentile would have no impacts on razorback sucker spawning. Lake elevations under both the Basin States and Conservation Before Shortage alternatives could be both above and below those under the No Action Alternative and would have no impact to razorback suckers. The increased amount of riverine habitat at the 10^{th} percentile of elevations could provide a minor positive impact to special status fish in the Colorado River inflow. Under the Water Supply Alternative there may be both minor positive and negative impacts to special status fish species due to providing more riverine habitat and lower elevations relative to razorback spawning areas, respectively, at the 50^{th} percentile. Under the Reservoir Storage Alternative, elevations could be above current razorback sucker spawning areas over 50 percent of the time in about half the modeled years, a moderate positive impact. Higher reservoir elevations would provide less riverine habitat for special status fish in the Colorado River inflow at the10^{th} and 50^{th} percentile elevations for a minor negative impact.

Hoover Dam to Davis Dam and Lake Havasu to Parker Dam. There is no substantial difference between the No Action Alternative and any of the action alternatives in this reach.

Davis Dam to Lake Havasu. Lower monthly and annual median releases from Davis Dam under the Reservoir Storage Alternative may have a minor negative impact on obligate phreatophytes, and marsh and associated special status bird species, and Colorado River cotton rat. Impacts to these species may occur through adverse effects to their habitats from reduced dam releases. Razorback sucker, flannelmouth sucker, and bonytail may experience a minor negative impact because lower potential releases could have adverse impacts to riverine spawning habitat and backwater rearing habitats that these species utilize. Higher monthly and annual median releases from Davis Dam under the Water Supply Alternative may have a minor positive impact on obligate phreatophytes, and marsh and associated special status bird species, and Colorado river cotton rat. razorback sucker, flannelmouth sucker, and bonytail may also benefit from these higher flows because they could maintain more of the spawning and rearing habitats present in this reach.

Parker Dam to Imperial Dam. Lower monthly and annual median flows under the Basin States, Conservation Before Shortage, and Reservoir Storage alternatives, and the Preferred Alternative, may have minor negative impacts to the habitats of the special status bird species and Colorado river cotton rat. Obligate phreatophytes, and marsh and associated special status species would be negatively impacted by lower releases. Razorback sucker and bonytail chub may be negatively impacted by lower flows under the Basin States, Conservation Before Shortage, and Reservoir Storage alternatives, and the Preferred Alternative. Lower flows may negatively impact spawning and rearing habitats for these species. Higher annual median flows under the Water Supply Alternative would benefit the habitats of special status birds, mammals and fish and may have a minor positive impact.

Imperial Dam to NIB. Under the No Action Alternative and the action alternatives there would be no impact to special status species in this reach. Flow changes in this reach would be limited to flows in the AAC rather than to the Colorado River downstream of Imperial Dam. No impacts to special status species are anticipated from flow differences in the AAC.

NIB to SIB. Flows past Morelos Diversion Dam are more probable under the Reservoir Storage and Conservation Before Shortage alternatives. The increased probability of flows may have a moderate positive impact on the special status bird species through positive impacts to riparian and marsh habitats these species utilize. These higher probabilities of flows may also positively impact the special status bat species listed in this section, Yuma hispid cotton rat, and Colorado river cotton rat through positive impacts to their riparian and marsh habitats. Though these flows are an overall benefit to the riparian corridor downstream of the NIB, the increased probability of high flows could increase the likelihood of scouring *Atriplex* vegetation in this reach, which would be a minor negative impact to MacNeill's sooty-winged skipper.

4.9 Cultural Resources

This section describes the methods used in the analysis of potential effects to cultural resources, including historic properties, Indian sacred sites, and issues of Tribal concern as a result of implementing the alternatives developed under the proposed federal action.

4.9.1 Methodology

This section provides a general analysis that considers how cultural sites might be exposed and affected by implementation of the proposed federal action. However, the specifics about current integrity of submerged sites and the impacts that might occur to these sites once they are exposed are mostly unknown. Because of this, Reclamation and NPS will work together to develop an agreement acceptable to the consulting parties that implements an appropriate strategy to identify, analyze, and address potential effects to cultural sites as they are exposed in the future as a consequence of implementing the proposed federal action.

For Lake Powell, the 10^{th} percentile was selected as the basis for effect determination because it represents the "worst case" that still has a reasonable probability of occurring. At Lake Mead, elevation 1,080 feet msl was selected as the basis for effect determination.[1] Processes that might result in a loss of integrity vary by reach and property type; consequently, methods of assessing effects differ by reach.

4.9.2 Lake Powell and Glen Canyon Dam

4.9.2.1 No Action Alternative

Under the No Action Alternative, the lowest projected elevation of Lake Powell under the 10^{th} percentile modeled Lake Powell elevations is 3,522 feet msl (Figure P-WAQ-6 in Appendix P). Some 194 unexcavated archaeological sites are at or above this elevation and would therefore be subject to erosion or visitor impacts.

4.9.2.2 Basin States Alternative and Conservation Before Shortage Alternative

Under the Basin States and Conservation Before Shortage alternatives, the lowest projected elevation of Lake Powell at the 10^{th} percentile of modeled Lake Powell elevations is 3,541 feet msl. Some 190 unexcavated archaeological sites are at or above this elevation and would therefore be subject to erosion or visitor impacts. This is essentially the same effect as under the No Action Alternative.

[1] Elevation 1,083 feet msl is the lowest elevation observed since Lake Mead filled.

4.9.2.3 Water Supply Alternative

Under the Water Supply Alternative, the lowest projected elevation of Lake Powell at the 10th percentile of modeled Lake Powell elevations is 3,496 feet msl. Some 227 unexcavated archaeological sites are at or above this elevation and would therefore be subject to erosion or visitor impacts. This is a greater number of affected sites than under the No Action Alternative.

4.9.2.4 Reservoir Storage Alternative

Under the Reservoir Storage Alternative, the lowest projected elevation of Lake Powell at the 10th percentile of modeled Lake Powell elevations is 3,538 feet msl. Some 193 unexcavated archaeological sites are at or above this elevation and would therefore be subject to erosion or visitor impacts. This is essentially the same effect as under the No Action Alternative.

4.9.2.5 Preferred Alternative

Under the Preferred Alternative, the lowest projected elevation of Lake Powell at the 10th percentile of modeled Lake Powell elevations is 3,543 feet msl. Some 190 unexcavated archaeological sites are at or above this elevation and would therefore be subject to potential erosion or visitor impacts. This is essentially the same effect as identified under the No Action Alternative.

4.9.3 Glen Canyon Dam To Lake Mead

The Colorado River reach between Glen Canyon Dam and Separation Canyon contains 336 NRHP-eligible properties. These are actively managed by the NPS, Navajo Nation and Hualapai Indian Tribe. In addition, Reclamation's NHPA Section 106 responsibilities for effects of Glen Canyon Dam operations are managed through a programmatic agreement. A treatment plan for mitigation of adverse impacts to historic properties is in development and will be implemented in 2008. The Grand Canyon Protection Act of 1992 ensures long-term mitigation of effects. Thus, the alternatives currently under analysis pose no additional threat to historic properties not already considered by existing programs.

4.9.4 Lake Mead and Hoover Dam

Some 32 previously recorded cultural resources are located at or below elevation 1,080 feet msl at Lake Mead, although many more undocumented cultural resources are probably submerged in Lake Mead at or below this elevation. If these cultural resources were to emerge, additional impacts would be anticipated as a result of invasion by invasive species of plants and animals (specifically as seen at St. Thomas by tamarisk and Asiatic freshwater clams), cracking and fissuring of sediments as a result of repeated wetting and drying and freeze/thaw cycles (Wyskup 2006), and as a result of visitor impacts. Resources like the B-29 Bomber aircraft, and the aggregate classification plant are currently at depths where they cannot be reached without specialized breathing-gas mixture and diving equipment, but a lowering of the reservoir elevation would bring these resources into the range of recreational divers.

4.9.4.1 No Action Alternative

The probability of Lake Mead elevation falling below 1,080 feet msl was analyzed in Section 4.3 and Table 4.3-22. Figure 4.3-22 present the probabilities of Lake Mead elevation falling below 1,080 feet msl over the period of analysis for all alternatives. Under the No Action Alternative, the probability begins at zero percent in 2008 and increases to 41 percent in 2060. From 2016 through 2040, the probability fluctuates between 39 percent and 45 percent.

4.9.4.2 Basin States Alternative and Conservation Before Shortage Alternative

In 2008, the probability of Lake Mead elevation falling below elevation 1,080 feet msl is zero under these action alternatives. In years 2016 through 2040, the probability is slightly higher (one to five percent) than under the No Action Alternative for several years and ranges between 40 percent and 46 percent. Given these small differences compared to the No Action Alternative, the differential effect on cultural resources would be negligible.

4.9.4.3 Water Supply Alternative

In 2008, the probability of Lake Mead elevation falling below 1,080 feet msl is zero. From 2016 through 2040, the probability fluctuates between 40 percent and 49 percent, a relative difference of about one to nine percent under the Water Supply Alternative compared to the No Action Alternative. Consequently, there is a higher probability that cultural resources submerged at or below elevation 1,080 feet msl would emerge under the Water Supply Alternative.

4.9.4.4 Reservoir Storage Alternative

In 2008, the probability of Lake Mead elevation falling below 1,080 feet msl is zero. The probability of the Lake Mead elevation falling below 1,080 feet msl is substantially lower (one percent to 13 percent) under this alternative compared to the No Action Alternative. Consequently, there is a lower probability that cultural resources submerged at or below elevation 1,080 feet msl would emerge under the Reservoir Storage Alternative.

4.9.4.5 Preferred Alternative

In 2008, the probability of Lake Mead elevation falling below 1,080 feet msl is zero. In 2016 the probability of Lake Mead elevation falling below elevation 1,080 feet msl is slightly lower (five percent) than under the No Action Alternative; and in 2017 through 2040, the probability is slightly higher (one to three percent) than under the No Action Alternative. Given these small differences compared to the No Action Alternative, the differential effect on cultural resources would be negligible.

4.9.5 Hoover Dam to Davis Dam

Under all alternatives, Lake Mohave would continue to be operated to meet monthly target elevations. Because there would be no change in reservoir operations, there is no potential for adverse effects to occur to cultural resources submerged in Lake Mohave as a result of the proposed federal action.

4.9.6 Davis Dam to Parker Dam

Geomorphic processes in lacustrine and fluvial environments differ, therefore, the Davis Dam to Parker Dam reach has been subdivided into sub-reaches for this analysis, a river reach and Lake Havasu.

4.9.6.1 Davis Dam to Upper Lake Havasu

There are ten previously recorded cultural resources located along the reach of the Colorado River from Davis Dam to the upstream end of Lake Havasu. Three of these cultural resources span the Colorado River with their end-points anchored in positions well above the river surface. A lowering of the elevation of the river in the area of these sites would have no direct or indirect effect on these resources. Examination of the site forms and map plots for two other previously recorded cultural resources, both being segments of railroads indicate that these sites are located in elevated positions back from the riverbank. No direct or indirect effects to these resources are anticipated as a result of the proposed federal action due to their elevated locations.

Of the five additional cultural resources in this reach, only two would be directly affected by a drop in river elevation. These two sites represent the remnants of two bridges used by contractors during the construction of Davis Dam.

Although the proposed federal action may result in reductions in the annual volume of water released from Davis Dam and the corresponding mean daily releases, the hourly releases will continue to fluctuate between the historical minimum and maximum ranges due to operational considerations and constraints. The corresponding river flows and associated elevations would also continue to fluctuate between the historical minimum and maximum ranges and therefore it is unlikely that there would be any changes in depositional or erosional processes along tributary streams or washes, or the Colorado River itself. Furthermore, it is highly unlikely that daily or hourly changes in elevation would result in conditions that would allow for more ready access to cultural resources located immediately adjacent to or in the river.

4.9.6.2 Lake Havasu and Parker Dam

Under the alternatives, Lake Havasu will continue to be operated to meet monthly target elevations. Because there will be no change in the manner in which the reservoir has been operated historically, there is no potential for effects to occur to cultural resources submerged in Lake Havasu.

4.9.7 Parker Dam to Imperial Dam

The Implementation Agreement FEIS (Reclamation 2002a) identified several cultural resource sites within or proximal to the Parker Dam to Imperial Dam reach. However, most of the historic resources that may be present in the APE, as suggested from plats and site records, have been destroyed by meandering and relocation of the mainstream channel of the Colorado River and agricultural development. Further, the proposed federal action will have no effect on Parker Dam, Imperial Dam or the Old Parker Road.

Although the proposed federal action may result in reductions in the annual volume released from Parker Dam and the corresponding mean daily releases, the hourly releases will continue to fluctuate between the historical ranges due to operational considerations and constraints. The corresponding river flows and associated elevations would also continue to fluctuate between the historical minimum and maximum ranges and therefore it is unlikely that there would be any changes in depositional or erosional processes along tributary streams or washes, or the Colorado River. Eleven of the twelve sites located proximate to the APE are situated in locations above the river channel, its connected lakes and backwaters, and floodplain. The anticipated changes in river elevations would therefore not impact these sites. Also, the prehistoric habitation site listed on the National Register would not be directly impacted by a drop in river elevation. It is conceivable that it could be indirectly impacted by better accessibility if the river drops in elevation more frequently or for longer periods of time. The probability of this occurring is small and would be countered by the emergence of impenetrable vegetation behind the retreating water line. Furthermore, it is highly unlikely that daily or hourly changes in elevation would result in conditions that would allow for more ready access to cultural resources located immediately adjacent to or in the river.

4.9.8 Sacred Sites and Other Issues of Tribal Concern

As a result of prior government-to-government consultations, several tribes had identified Indian sacred sites located on federal lands within the affected environment. During consultations regarding this proposed federal action, the Hualapai Indian Tribe was the only tribe who specifically raised a concern regarding how the alternatives might adversely affect the physical integrity of sacred sites. The Hualapai Indian Tribe also raised concerns regarding biological resources located in Grand Canyon and on Hualapai Tribal land.

Reclamation, NPS, and FWS (federal agencies who manage lands within the affected environment) remain committed to accommodating access to and ceremonial use of Indian sacred sites by Indian religious practitioners. The agencies also remain committed to avoiding any adverse effects to the physical integrity of such sites in compliance with Exec. Order No. 13007. None of the alternatives are anticipated to adversely affect any identified Indian sacred site or alter access to such a site.

During consultation for this proposed federal action, several tribes expressed concern that the alternatives might result in inadvertent discoveries of Native American human remains or cultural items as defined under the Native American Graves Protection and Repatriation Act of 1990 (NAGPRA). Reclamation and the federal land-managing agencies remain committed to compliance with both the inadvertent discovery and museum inventory sections of this law and its implementing regulations.

With respect to museum inventories from the original Glen Canyon archaeological project, Reclamation is working on cultural affiliation determinations on behalf of tribes seeking repatriation of inventory items from the Glen Canyon archaeological project.

4.9.9 Summary

For Lake Powell, under the Water Supply Alternative at the 10th percentile, there are at least 227 unexcavated sites subject to effect, as compared to about 193 sites under the other alternatives. Consultation is underway regarding eligibility and effect.

For the reach from Glen Canyon to Lake Mead, the alternatives pose no additional threat to cultural resources because of the programs already underway.

For Lake Mead, there are at least 32 cultural resources located below elevation 1,080 feet msl. The probability of exposing sites below this elevation vary by alternative, with the Reservoir Storage Alternative having the lowest probability (up to 13 percent lower compared to the No Action Alternative) and the Water Supply Alternative having the highest probability (up to nine percent higher compared to the No Action Alternative). The Basin States and Conservation Before Shortage alternatives and the Preferred Alternative have probabilities similar to those of the No Action Alternative.

For reaches downstream of Lake Mead, no adverse effects are anticipated from any of the alternatives. However, consultation regarding eligibility and effect will be undertaken.

For Indian sacred sites and other issues of Tribal concern (not including ITAs), none of the alternatives are expected to restrict access or result in loss of physical integrity to sacred sites. Consultations with Indian tribes are ongoing with respect to these issues and other issues and concerns.

4.10 Indian Trust Assets

4.10.1 Water Rights and Trust Lands

No 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.

To the extent that additional Tribal water rights are developed, established or quantified during the interim period of the proposed federal action, the United States will manage Colorado River facilities to deliver water consistent with such additional water rights, if any, pursuant to federal law. Thus, modifications to system operations, in accordance with pertinent legal requirements, will consider Tribal water rights, and will be exercised in accordance with applicable law.

Water deliveries to the Fort Mojave, Chemehuevi, CRIT, and Fort Yuma Indian Reservations will not be affected by the proposed federal action due to their early priority dates. For the Cocopah Indian Reservation, its 1915 and 1917 PPRs would also not be affected. However, the 1974 priority date of 2,026 afy of the Cocopah Indian Reservation may be reduced during certain shortage conditions, as summarized in Section 4.4 (Water Deliveries). Similarly, the CAP Settlement tribes, with their post-1968 CAP Priority, would also be subject to shortages. However, even when water deliveries are reduced to these Indian Reservations, the underlying water rights would not be affected.

Water delivery reductions may result in fallowing of some Indian lands; however, these changes in land-use are expected to be temporary and no permanent changes in land-use would occur. In terms of effects to the shorelines of reservations that abut to the affected reservoirs or river reaches, the fluctuations that might occur as a result of this action downstream of Lake Mead are projected to be within historic levels.

For the action alternatives, the distribution of average daily releases may change (Table 4.3-13) from those under the No Action Alternative, but the operations would still be within the parameters of the 1996 Glen Canyon Dam ROD (Section 3.3). These occasional flow reductions and the concomitant sediment transport difference past the boundaries of the Navajo Nation and the Hualapai Indian Reservation would not affect Indian trust lands.

4.10.2 Hydroelectric Power Generation and Distribution

The energy generated at Headgate Rock Powerplant under the Basin States, Conservation Before Shortage, and Reservoir Storage alternatives, and the Preferred Alternative could potentially be less than the energy generated under the No Action Alternative (Section 4.11). These reductions in energy generation range from 1.3 percent to 2.8 percent (Table 4.11-23). However, Reclamation has determined that water appropriated to non-CRIT entities that flows through Headgate Rock Dam and generates electricity is not an ITA.

4.10.3 Cultural Resources

Reclamation is currently in the process of identifying cultural resources and evaluating potential effects of implementing the proposed federal action (Section 4.9). However, based on what is currently known of Tribal historic and traditional cultural properties, there would be no effect on cultural resources of concern to the tribes. Furthermore, under Exec. Order No. 13007, there would be no change in access to Tribal sacred sites as a result of the proposed federal action.

4.10.4 Biological Resources

While not necessarily ITAs, the Navajo Nation and the Hualapai Indian Tribe have expressed concern over biological resources located on their reservations and in the intervening Grand Canyon. The action alternatives would result in occasional changes of flows past the Navajo Nation and the Hualapai Indian Reservation, compared with the No Action Alternative (Section 4.8). These flows would have some potential to affect phreatophytes such as willow (a plant of concern to many tribes); however, the effects are likely to be short-term, especially in comparison to the long-term trends favoring tamarisk expansion.

The Navajo Nation and the Hualapai Indian Tribe also expressed concern over native fish. The Hualapai Indian Tribe is particularly concerned with razorback sucker in the upper end of Lake Mead. The modeling of Lake Mead elevations indicates that the minimum Lake Mead elevations under the action alternatives would be similar to those under the No Action Alternative (Section 4.8). Therefore, the proposed federal action is expected to have either no effects or only minor effects on razorback sucker and other fish of Tribal concern.

4.10.5 Summary

After analyzing each resource, it is concluded that Tribal trust assets identified in the study area would not be adversely affected by any of the anticipated environmental impacts stemming from the proposed federal action.

4.11 Electrical Power Resources

This section analyzes the potential effects of the proposed federal action on electrical power (or hydropower) resources. The following issues are addressed:

- change in electrical power generated and the associated change in economic value;
- effect on Upper and Lower Colorado Basin funds that pay for operation, maintenance, replacements of power facilities, and other programs supported by these funds;
- financial implications associated with implementation of surcharges;
- potential impact to ancillary services; and
- change in annual cost of electrical power for pumping water associated with the Navajo Generating Station, City of Page water supply system, SNWA water supply system, and CAP pumping load.

4.11.1 Methodology

Reclamation conducted a study of the potential effects of the action alternatives on electrical power resources of the Colorado River system that included all major facilities with the exception of generation capacity at the Glen Canyon Powerplant. Western conducted a parallel analysis of the potential effects of the action alternatives only on Glen Canyon Powerplant (Appendix O). The two studies show very similar trends among the alternatives and the relative findings of each study are comparable. Western's analytical methodology includes a more detailed hourly analysis of the capacity of the Glen Canyon Powerplant because of operational limitations of hydropower facilities resulting from the 1996 Glen Canyon Dam ROD. The results of Reclamation's analysis are used throughout this section with the exception of the analysis of generation capacity and the economic value of generation capacity of the Glen Canyon Powerplant, which uses the results of the hourly analysis conducted by Western.

4.11.1.1 Electrical Energy Generated

The basis for the electrical power analysis is the CRSS model described in Section 4.2 and Appendix A of this final EIS. Among other variables, the model simulates monthly turbine release (af) and end-of-month reservoir elevation (feet msl) and calculates monthly generation (MWh) and monthly capacity (MW). The monthly generation data were then aggregated to produce estimates of annual generation. Using the resulting annual data, the mean, median, 90th percentile, and 10th percentile annual energy generation statistics were calculated for each year for the Glen Canyon, Hoover, Parker, and Davis Powerplants.

Since the reservoir behind Headgate Rock Dam is maintained at a relatively constant elevation, electrical power generation at the Headgate Rock Powerplant was calculated based on modeling changes in river flows provided by the CRSS model for the

No Action Alternative and the action alternatives. The modeled flows available to pass through the Headgate Rock Powerplant were first reduced by a factor of 5.96 percent to account for water that is likely to be bypassed through the Colorado River gates. This factor was derived from actual 2001 through 2005 data. Energy was then calculated using a conversion factor of 12.97 kWh/af, derived by averaging the monthly kWh/af values for the Headgate Rock Powerplant from 1996 through 1998.

In general, mean values provide an assessment of the overall impact to hydropower. The mean is the average of all modeled traces, which includes all hydrologic extremes, while the median is the midpoint of all values. Mean energy values higher than median values reflect water released from Glen Canyon Dam for equalization and the existence of the minimum objective release. Mean energy values lower than median values at the Hoover Powerplant are likely due to extreme dry conditions when Hoover Powerplant may not be generating power.

4.11.1.2 Generation Capacity

Using the capacity relationships for each powerplant, their respective monthly availability factors and the monthly forebay elevations simulated by the CRSS model, the monthly generation capacity for each powerplant was computed. The mean, median, 90^{th} percentile and 10^{th} percentile capacity values were then computed for the No Action Alternative and the action alternatives for the Glen Canyon, Hoover, Parker, and Davis Powerplants. For the Glen Canyon Powerplant, the analysis was conducted by Western (Appendix O). Capacity was not calculated for the Headgate Rock Powerplant because no changes in capacity are anticipated due to the constant elevation that is maintained in the upstream impoundment.

4.11.1.3 Economic Values

The economic value of operating an existing hydroelectric powerplant varies considerably with time of day. The cost of meeting demand varies on a second-by-second basis depending on the load, the mix of powerplants being operated to meet load, and their output levels. During off-peak periods, demand is typically satisfied with lower-cost coal, run-of-river hydropower, and nuclear units. During on-peak periods, the additional load is met with more expensive sources such as gas turbine units. Consequently, the economic value of hydropower is greatest during the hours when the demand for electricity, and the variable cost of meeting demand, is the highest.

The electrical energy prices used in this analysis were developed from both an hourly price forecast keyed to the Palo Verde Interchange and mean monthly reported price indices for the Palo Verde Interchange obtained from Dow Jones, Inc. The hourly forecast of 2004 electricity prices at the Palo Verde Interchange was developed using the AURORA model (Electric Power Information Solutions, Inc. 2005).

AURORA model simulations used in this analysis were developed for and used in the Northwest Power and Conservation Council's (NWPCC) Fifth Northwest Electric Power and Conservation Plan (NWPCC 2005). The NWPCC is primarily interested in Northwestern electricity markets. Relatively less attention is devoted to characterizing market conditions in other areas. Consequently, the forecast described in this analysis primarily reflects the default data supplied with the AURORA model.

For purposes of this analysis, the hourly prices developed using the AURORA model were scaled to match the mean monthly reported prices purchased from Dow Jones, Inc. The resulting (scaled) hourly prices exhibit the expected daily, weekly and monthly patterns of price behavior and reflect the mean values actually observed in each month.

The underlying hourly prices yielded by this process are for 2004. These prices were escalated by 2.2 percent per year to estimate 2008 prices. For this analysis, estimates of the economic value for the No Action Alternative and each of the action alternatives were analyzed using monthly generation data simulated by the CRSS model. The monthly generation values were then analyzed using the escalated mean price of electricity for that month. The monthly economic value was then aggregated to produce estimates of annual economic value.

The costs and benefits associated with electrical power generation are incurred at different times over a long period of time. Because the timing of these costs and benefits differ across the alternatives, the present value of the future stream of costs and benefits for each alternative was computed as a means of assessing the economic value of electrical power for each alternative.

All economic value estimates reported in this Final EIS are measured in present value 2008 dollars (PV 2008 $). All annual costs and benefits subsequent to 2008 were escalated by 2.2 percent per year and discounted back to the 2008 base year using a discount rate of 4.875 percent.

Similar to the process used in the economic analysis of electrical energy generation, the present value of generation capacity was analyzed. In this instance, the capacity was valued at $6.32/kW-month based upon the alternative market cost of capacity.

4.11.2 Electrical Power Generation Facilities

4.11.2.1 Glen Canyon Powerplant

No Action Alternative. The No Action Alternative values for annual energy generation, monthly generation capacity, and economic value at Glen Canyon Powerplant for the mean, median, 90th percentile, and 10th percentile values are presented in Table 4.11-1.

Table 4.11-1
No Action Alternative Values at Glen Canyon Powerplant

Measure	Mean	Median	90th Percentile	10th Percentile
Annual Energy Generation (MWh)	4,247,880	3,748,420	6,312,730	3,130,880
Monthly Capacity (MW)	606	546	839	451
Economic Value of Electrical Power Generation - Total (PV 2008 $ million)	7,350	6,523	10,663	5,436

Comparison of Action Alternatives to No Action Alternative. Table 4.11-2 presents the change in annual electrical energy generation for each alternative in MWh in comparison to the No Action Alternative, for the mean, median, 90th percentile, and 10th percentile values.

Table 4.11-2
Change in Glen Canyon Powerplant Annual Energy Generation (MWh)

Action Alternative	Mean	Median	90th Percentile	10th Percentile
Basin States	(3,610)	51,210	(38,020)	(92,680)
Conservation Before Shortage	(2,990)	50,570	(36,450)	(92,910)
Water Supply	(109,120)	34,830	(98,710)	(226,660)
Reservoir Storage	33,170	20,360	61,490	3,600
Preferred Alternative	3,460	46,250	(26,610)	(75,130)

Table 4.11-3 presents the percent change in annual energy generation for each alternative, in comparison to the No Action Alternative, for the mean, median, 90th percentile, and 10th percentile values.

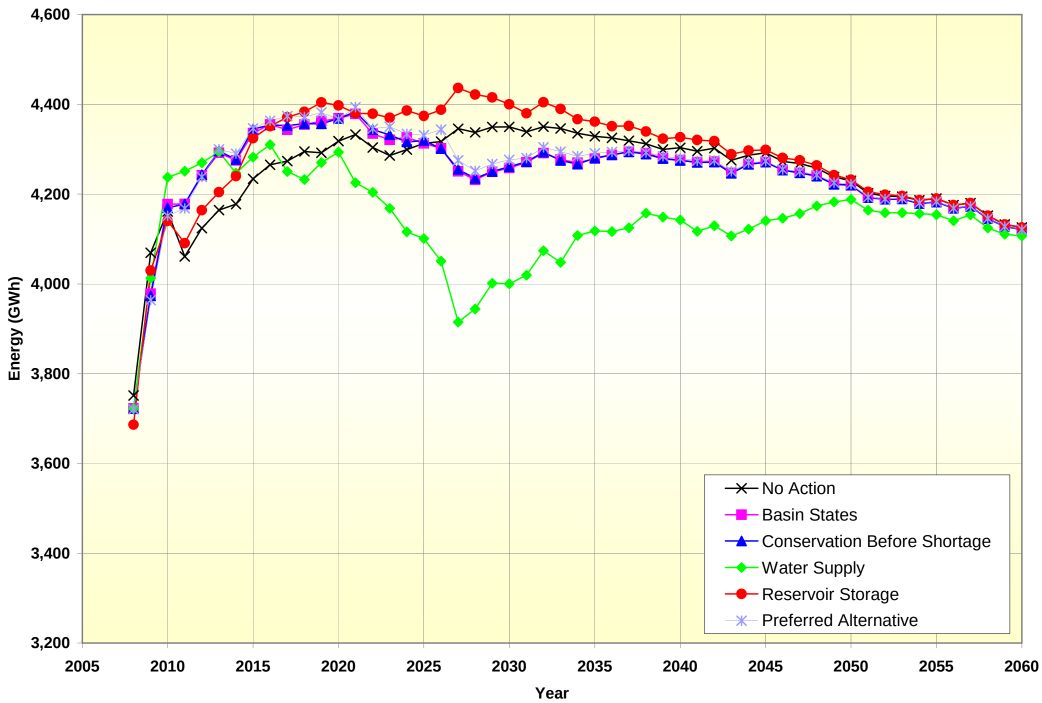
Table 4.11-3
Change in Glen Canyon Powerplant Annual Generation (percent)

Action Alternative	Mean	Median	90th Percentile	10th Percentile
Basin States	(0.08)	1.37	(0.60)	(2.96)
Conservation Before Shortage	(0.07)	1.35	(0.58)	(2.97)
Water Supply	(2.57)	0.93	(1.56)	(7.24)
Reservoir Storage	0.78	0.54	0.97	0.11
Preferred Alternative	0.08	1.23	(0.43)	(2.40)

Figure 4.11-1 shows average values of annual electrical energy production in gigawatt-hours (GWh) for the Glen Canyon Powerplant, over the period of study, for the action alternatives, and the No Action Alternative. Differences in mean generation values between the No Action Alternative and the action alternatives are the greatest from 2020 through 2050.

Western conducted a complementary study of energy generation and associated economic value using an hourly time-step to simulate hourly Glen Canyon Powerplant generation levels. Western's model was used to determine the hourly operation schedule that maximized the economic value of the hydropower resource. Hourly pricing data, inflation and discount rates used in Western's study were the same as those used by Reclamation.

Figure 4.11-1
Glen Canyon Powerplant
Average Annual Electrical Energy Production



The Western study also included an analysis of the impacts to generation capacity at the Glen Canyon Powerplant. Table 4.11-4 presents the change in generation capacity for each alternative, as compared to the No Action Alternative, for the mean, median, 90th percentile, and 10th percentile values. The corresponding percentage changes are identified in Table 4.11-5.

Table 4.11-4
Change in Glen Canyon Powerplant Generation Capacity (MW)

Action Alternative	Mean	Median	90th Percentile	10th Percentile
Basin States	(0.88)	6.04	(0.79)	(15.12)
Conservation Before Shortage	(0.79)	6.09	(0.74)	(15.01)
Water Supply	(16.50)	3.71	(9.65)	(33.91)
Reservoir Storage	4.81	2.87	6.75	(2.55)
Preferred Alternative	0.18	5.49	0.24	(12.41)

Table 4.11-5
Change in Glen Canyon Powerplant Generation Capacity (percent)

Action Alternative	Mean	Median	90th Percentile	10th Percentile
Basin States	(0.15)	1.11	(0.09)	(3.35)
Conservation Before Shortage	(0.13)	1.12	(0.09)	(3.33)
Water Supply	(2.72)	0.68	(1.15)	(7.52)
Reservoir Storage	0.79	0.53	0.80	(0.57)
Preferred Alternative	0.03	1.01	0.03	(2.75)

Table 4.11-6 presents the change in total economic value of electrical power generation for each alternative, as compared to the No Action Alternative for the mean, median, 90th percentile, and 10th percentile values. Table 4.11-7 presents the corresponding percentage change in net present value for each alternative as compared to the No Action Alternative for the mean, median, 90th percentile, and 10th percentile values.

Table 4.11-6
Change in Glen Canyon Powerplant Total Economic Value of Electrical Power Generation (PV 2008 $ million)

Action Alternative	Mean	Median	90th Percentile	10th Percentile
Basin States	1.70	126.57	(60.55)	(212.78)
Conservation Before Shortage	2.86	125.07	(57.90)	(212.17)
Water Supply	(165.72)	112.08	(151.39)	(426.17)
Reservoir Storage	64.72	41.70	108.40	(35.31)
Preferred Alternative	14.26	111.43	(40.61)	(178.60)

Table 4.11-7
Change in Glen Canyon Powerplant Total Economic Value of Electrical Power Generation (percent)

Action Alternative	Mean	Median	90th Percentile	10th Percentile
Basin States	0.02	1.94	(0.57)	(3.91)
Conservation Before Shortage	0.04	1.92	(0.54)	(3.90)
Water Supply	(2.25)	1.72	(1.42)	(7.84)
Reservoir Storage	0.88	0.64	1.02	(0.65)
Preferred Alternative	0.19	1.71	(0.38)	(3.29)

Under all the action alternatives, the greatest impact to power would occur in the dry years. The Reservoir Storage Alternative provides an increased electrical power generation value, as a result of higher reservoir elevations, while the other action alternatives show generally decreased electrical power generation values.

4.11.2.2 Hoover Powerplant

No Action Alternative. The No Action Alternative values for annual energy generation, monthly generation capacity, and economic value at the Hoover Powerplant for the mean, median, 90th percentile, and 10th percentile values are presented in Table 4.11-8.

Table 4.11-8
No Action Alternative Values at Hoover Powerplant

Measure	Mean	Median	90th Percentile	10th Percentile[1]
Annual Energy Generation (MWh)	3,127,523	3,675,298	5,188,960	0.0
Monthly Capacity (MW)	1,191	1,424	2,069	0.0
Economic Value of Electrical Power Generation - Total (PV 2008 $ million)	7,223	8,395	10,453	3,185

1 *The 10th percentile value for capacity and energy is zero on cumulative distribution function graphs of end-of-December capacity and energy, a result of Lake Mead elevation being less than 1,050 feet msl (the assumed minimum power head). This result cascades in calculating total generation and percentage changes in Tables 4.11-9 through 4.11-14.*

Comparison of Action Alternatives to No Action Alternative. Table 4.11-9 presents the change in annual electrical energy generation in MWh for each action alternative, in comparison to the No Action Alternative, for the mean, median, 90th percentile, and 10th percentile values.

Table 4.11-9
Change in Hoover Powerplant Annual Electrical Energy Generation (MWh)

Action Alternative	Mean	Median	90th Percentile	10th Percentile
Basin States	(6,960)	(46,952)	(15,193)	0.0
Conservation Before Shortage	(1,544)	(51,927)	(10,080)	0.0
Water Supply	(74,646)	(22,550)	(70,747)	0.0
Reservoir Storage	283,813	(55,065)	96,443	0.0
Preferred Alternative	43,772	(71,765)	6,843	0.0

Table 4.11-10 presents the percent change in annual electrical energy generation for each action alternative, in comparison to the No Action Alternative, for the mean, median, 90th percentile, and 10th percentile values.

Table 4.11-10
Change in Hoover Powerplant Annual Electrical Energy Generation (percent)

Action Alternative	Mean	Median	90th Percentile	10th Percentile
Basin States	(0.22)	(1.28)	(0.29)	0.0
Conservation Before Shortage	(0.05)	(1.41)	(0.19)	0.0
Water Supply	(2.39)	(0.61)	(1.36)	0.0
Reservoir Storage	9.07	(1.50)	1.86	0.0
Preferred Alternative	1.40	(1.95)	0.13	0.0

Figure 4.11-2 depicts average values of annual electrical energy production for Hoover Powerplant over the period of study for each alternative, including the No Action Alternative. Differences in mean generation values between the No Action Alternative and the action alternatives are the greatest from 2020 through 2050.

Figure 4.11-2
Hoover Powerplant
Average Annual Electrical Energy Production

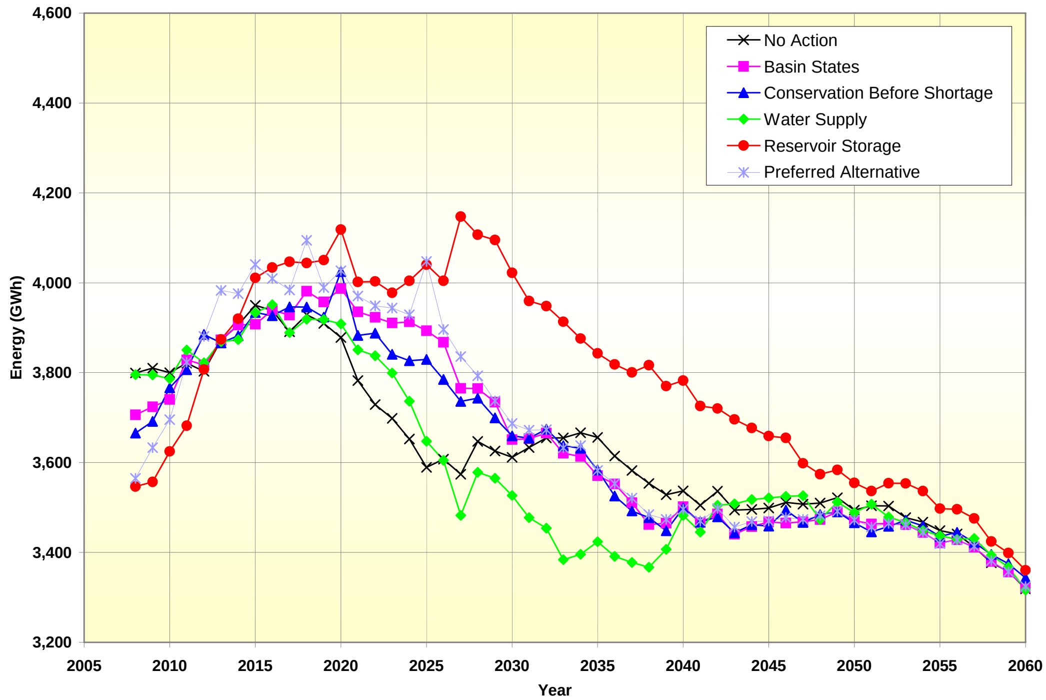


Table 4.11-11 presents the change in Hoover Powerplant monthly generation capacity (MW) for the action alternatives compared to the No Action Alternative for the mean, median, 90th percentile, and 10th percentile values.

Table 4.11-11
Change in Hoover Powerplant Monthly Generation Capacity (MW)

Action Alternative	Mean	Median	90th Percentile	10th Percentile
Basin States	3.7	2.2	0.6	0.0
Conservation Before Shortage	6.9	5.1	0.9	0.0
Water Supply	(30.5)	(13.0)	(0.5)	0.0
Reservoir Storage	137.2	56.6	4.9	0.0
Preferred Alternative	27.6	16.1	1.3	0.0

Table 4.11-12 presents the percentage change in the Hoover Powerplant monthly capacity for each of the action alternatives as compared to the No Action Alternative for the mean, median, 90th percentile, and 10th percentile values.

Table 4.11-12
Change in Hoover Powerplant Monthly Generation Capacity (percent)

Action Alternative	Mean	Median	90th Percentile	10th Percentile
Basin States	0.31	0.15	0.03	0.0
Conservation Before Shortage	0.58	0.36	0.04	0.0
Water Supply	(2.56)	(0.91)	(0.03)	0.0
Reservoir Storage	11.52	3.97	0.24	0.0
Preferred Alternative	2.31	1.13	0.06	0.0

Table 4.11-13 presents the change in each of the action alternatives as compared to the net present value of the total electrical power generation under the No Action Alternative for the mean, median, 90th percentile, and 10th percentile values.

Table 4.11-13
Change in Hoover Powerplant Total Economic Value of Electrical Power Generated (PV 2008 $ million)

Action Alternative	Mean	Median	90th Percentile	10th Percentile
Basin States	5.86	(269.01)	(16.1)	(87.19)
Conservation Before Shortage	24.34	(265.45)	(8.7)	(82.9)
Water Supply	(181.0)	(479.69)	(30.34)	(270.47)
Reservoir Storage	768.15	307.14	49.13	1,551.99
Preferred Alternative	172.13	(163.23)	25.62	163.95

Table 4.11-14 presents the corresponding percentage change in net present value for each alternative as compared to the No Action Alternative for the mean, median, 90th percentile, and 10th percentile values.

Table 4.11-14
Change in Hoover Powerplant Total Economic Value of Electrical Power Generated (percent)

Action Alternative	Mean	Median	90th Percentile	10th Percentile
Basin States	0.08	(3.20)	(0.15)	(2.74)
Conservation Before Shortage	0.34	(3.16)	(0.08)	(2.60)
Water Supply	(2.51)	(5.71)	(0.29)	(8.49)
Reservoir Storage	10.63	3.66	0.47	48.73
Preferred Alternative	2.38	(1.94)	0.25	5.15

In general, the Reservoir Storage Alternative and the Preferred Alternative provide the greatest increase in electrical power generation value at the Hoover Powerplant, while the Water Supply Alternative proves most adverse to power generation. The Basin States and Conservation Before Shortage alternatives show similar results and they are ranked between the Reservoir Storage Alternative and the Water Supply Alternative in their effect on power resources at the Hoover Powerplant.

4.11.2.3 Parker and Davis Powerplants

No Action Alternative. The No Action Alternative values for annual energy generation, monthly generation capacity, and total economic value for the Parker and Davis Powerplants for the mean, median, 90th percentile, and 10th percentile values are presented in Table 4.11-15.

Table 4.11-15
No Action Alternative Values at Parker and Davis Powerplants

Measure	Mean	Median	90th Percentile	10th Percentile
Annual Energy Generation (MWh)	1,639,687	1,581,530	1,820,271	1,506,057
Monthly Capacity (MW)	331.4	364.0	364.0	285.8
Economic Value of Electrical Power Generation - Total (PV (2008 $ million)	2,268	2,288	2,380	2,156

Comparison of Action Alternatives to No Action Alternative. Table 4.11-16 presents the change in annual electrical energy generation in MWh for each action alternative, in comparison to the No Action Alternative, for the mean, median, 90th percentile, and 10th percentile values.

Table 4.11-16
Change in Parker and Davis Powerplants Annual Electrical Energy Generation (MWh)

Action Alternative	Mean	Median	90th Percentile	10th Percentile
Basin States	(9,188)	(9,406)	(574)	(9,325)
Conservation Before Shortage	(11,363)	(12,380)	(176)	(11,029)
Water Supply	1,737	14,057	(12,449)	2,976
Reservoir Storage	(17,478)	(24,259)	(29,860)	(22,397)
Preferred Alternative	(11,214)	(14,561)	3,039	(13,763)

Table 4.11-17 presents the percent change in generation between the No Action Alternative and the action alternatives for the Parker and Davis Powerplants for the mean, median, 90th percentile, and 10th percentile values.

Table 4.11-17
Change in Parker and Davis Powerplants Annual Electrical Energy Generation (percent)

Action Alternative	Mean	Median	90th Percentile	10th Percentile
Basin States	(0.56)	(0.59)	(0.03)	(0.62)
Conservation Before Shortage	(0.69)	(0.78)	(0.01)	(0.73)
Water Supply	0.11	0.89	(0.68)	0.20
Reservoir Storage	(1.07)	(1.53)	(1.64)	(1.49)
Preferred Alternative	(0.68)	(0.92)	0.17	(0.91)

Table 4.11-18 shows that no changes are anticipated in monthly generation capacity under the action alternatives for the mean, median, 90th percentile, and 10th percentile values.

Table 4.11-18
Change in Parker and Davis Powerplants Monthly Generation Capacity (MW)

Action Alternative	Mean	Median	90th Percentile	10th Percentile
Basin States	0.0	0.0	0.0	0.0
Conservation Before Shortage	0.0	0.0	0.0	0.0
Water Supply	0.0	0.0	0.0	0.0
Reservoir Storage	0.0	0.0	0.0	0.0
Preferred Alternative	0.0	0.0	0.0	0.0

Figure 4.11-3 and Figure 4.11-4 depict average values of annual electrical energy production for the Parker Powerplant and Davis Powerplant, respectively, comparing the action alternatives to the No Action Alternative.

An observation from Figures 4.11-3 and 4.11-4 is a spike in energy production in 2025. This spike is due to a modeling assumption with regard to the storage and delivery mechanism and the modeled depletion schedules which withdraw a large volume of the storage credits in 2025.

Figure 4.11-3
Parker Powerplant
Average Annual Electrical Energy Production

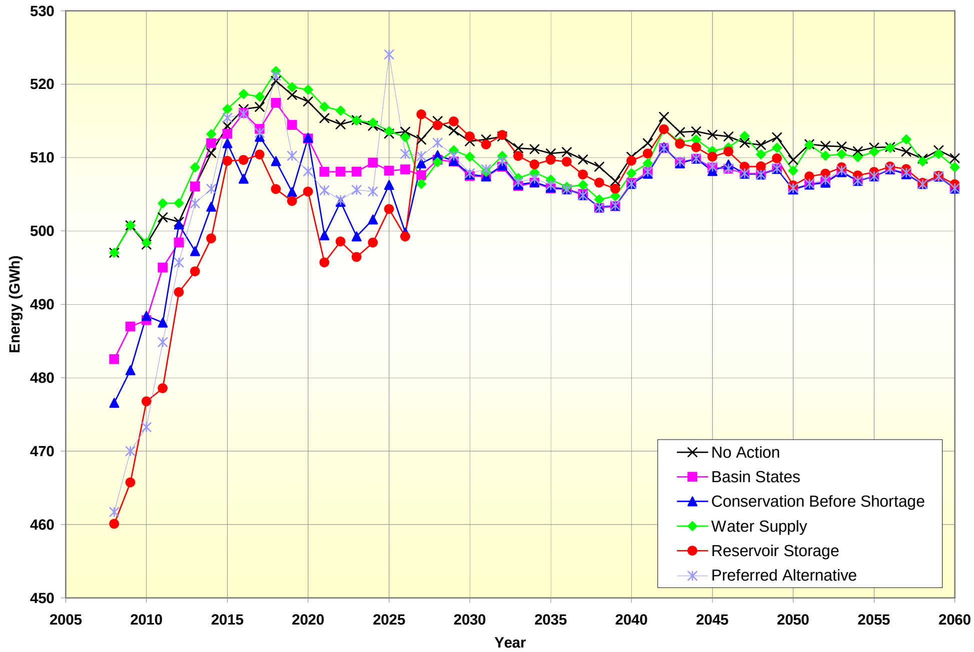
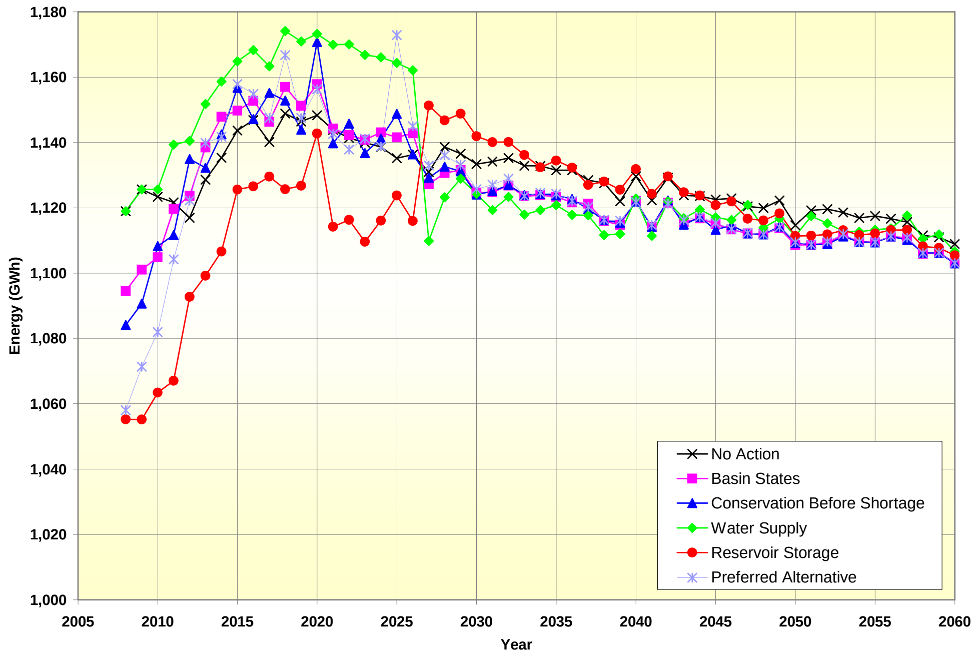


Figure 4.11-4
Davis Powerplant
Average Annual Electrical Energy Production



Economic value comparisons between the No Action Alternative and the action alternatives are presented in Table 4.11-19 for the mean, median, 90th percentile, and 10th percentile values.

Table 4.11-19
Change in Parker and Davis Powerplants Total Economic Value of Electrical Power Generation (PV 2008 $ million)

Action Alternative	Mean	Median	90th Percentile	10th Percentile
Basin States	(12.02)	(10.95)	(11.31)	(12.99)
Conservation Before Shortage	(16.66)	(16.50)	(12.09)	(19.16)
Water Supply	7.05	7.32	3.68	8.70
Reservoir Storage	(34.94)	(30.61)	(27.38)	(49.61)
Preferred Alternative	(18.32)	(17.57)	(14.23)	(20.08)

Table 4.11-20 presents the percent change in economic value between the No Action Alternative and each of the action alternatives for the mean, median, 90th percentile, and 10th percentile values.

Table 4.11-20
Change in Parker and Davis Powerplants Total Economic Value of Electrical Power Generated (percent)

Action Alternative	Mean	Median	90th Percentile	10th Percentile
Basin States	(0.53)	(0.48)	(0.48)	(0.60)
Conservation Before Shortage	(0.73)	(0.72)	(0.51)	(0.89)
Water Supply	0.31	0.32	0.15	0.40
Reservoir Storage	(1.54)	(1.34)	(1.15)	(2.30)
Preferred Alternative	(0.81)	(0.77)	(0.60)	(0.93)

In general, the Basin States and Conservation Before Shortage alternatives, and the Preferred Alternative could potentially provide a slight decline in the economic value of electrical power generated at Parker and Davis Powerplants. The Reservoir Storage Alternative is expected to result in a greater decline in economic values. The Water Supply Alternative results in slight increases in economic value for the Parker and Davis Powerplants.

Because of downstream requirements (i.e., environmental, plant operations, water requirements) the forebay elevations at Parker and Davis Powerplants remain relatively constant and electrical power generation is proportional to inflow. Consequently, the maximum generation capacity at Parker and Davis Powerplants will not be affected by the any of the action alternatives.

4.11.2.4 Headgate Rock Powerplant

No Action Alternative. The No Action Alternative values for annual generation and economic value at the Headgate Rock Powerplant for the mean, median, 90th percentile, and 10th percentile values are presented in Table 4.11-21.

Table 4.11-21
No Action Alternative Values at Headgate Rock Power Plant

Measure	Mean	Median	90th Percentile	10th Percentile
Annual Energy Generation (MWh)	77,482	73,698	85,069	69,611
Economic Value of Electrical Power Generation (PV 2008 $ million)	103	98	113	93

Comparison of Action Alternatives to No Action Alternative. Table 4.11-22 presents the change in annual generation in MWh for each action alternative relative to the No Action Alternative. The Water Supply Alternative provides higher median electrical energy generation due to the higher observed flows as compared to the No Action Alternative. The Basin States, Conservation Before Shortage, and Reservoir Storage alternatives, and the Preferred Alternative provided lower electrical energy generation as compared to the No Action Alternative for the mean, median, 90th percentile, and 10th percentile values.

Table 4.11-22
Change in Headgate Rock Powerplant Annual Electrical Energy Generation (MWh)

Action Alternative	Mean	Median	90th Percentile	10th Percentile
Basin States	(934)	(972)	(444)	(1,168)
Conservation Before Shortage	(1,322)	(1,252)	(509)	(1,946)
Water Supply	(216)	168	(716)	83
Reservoir Storage	(1,319)	(2,078)	1,164	(2,233)
Preferred Alternative	(1,164)	(1,283)	(437)	(1,817)

Table 4.11-23 presents the percent change in annual electrical energy generation for each action alternative relative to the No Action Alternative for the mean, median, 90th percentile, and 10th percentile values.

Table 4.11-23
Change in Headgate Rock Powerplant Annual Electrical Energy Generation (percent)

Action Alternative	Mean	Median	90th Percentile	10th Percentile
Basin States	(1.21)	(1.32)	(0.52)	(1.68)
Conservation Before Shortage	(1.71)	(1.70)	(0.60)	(2.80)
Water Supply	(0.28)	0.23	(0.84)	0.12
Reservoir Storage	(1.70)	(2.82)	1.37	(3.21)
Preferred Alternative	(1.50)	(1.74)	(0.51)	(2.61)

Figure 4.11-5 depicts average values of annual electrical energy production for Headgate Rock Powerplant, comparing the No Action Alternative and the action alternatives.

Figure 4.11-5
Headgate Rock Powerplant
Average Annual Electrical Energy Production

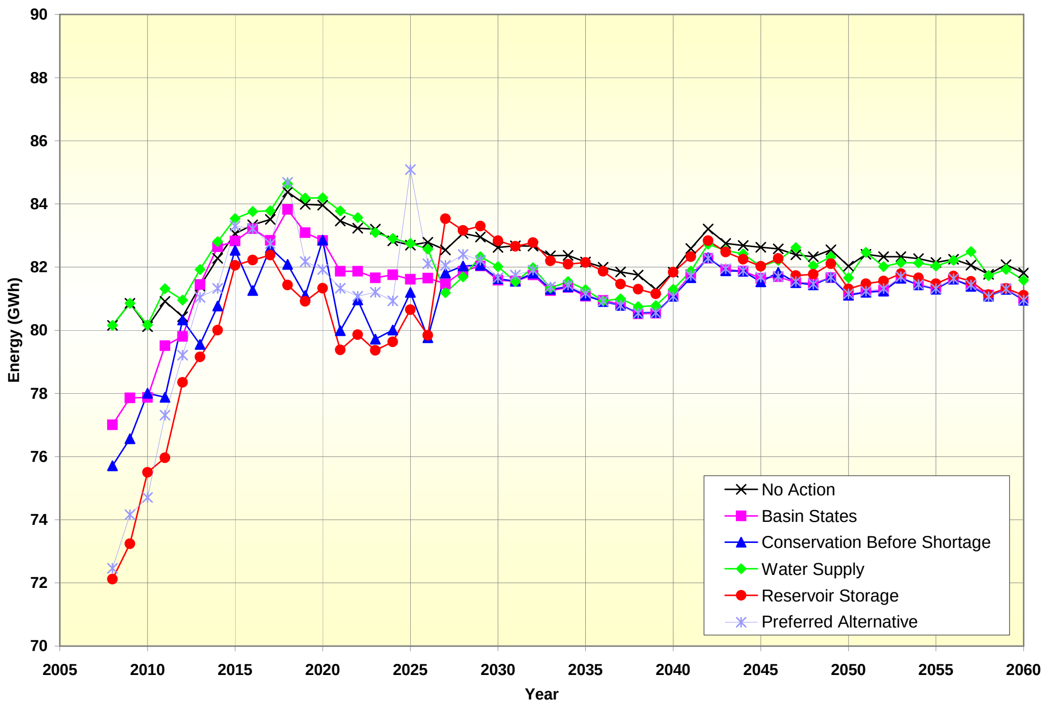


Table 4.11-24 provides an overview of the potential change in economic value of electrical power generated for each action alternative relative to the No Action Alternative for the mean, median, 90th percentile, and 10th percentile values.

Table 4.11-24
Change in Headgate Rock Powerplant Total Economic Value of Electrical Power Generated (PV 2008 $ million)

Action Alternative	Mean	Median	90th Percentile	10th Percentile
Basin States	(1.33)	(1.43)	(0.43)	(1.89)
Conservation Before Shortage	(2.08)	(2.08)	(0.52)	(3.52)
Water Supply	(0.18)	0.30	(0.86)	0.23
Reservoir Storage	(2.38)	(3.73)	1.46	(4.32)
Preferred Alternative	(1.89)	(2.19)	(0.54)	(3.41)

Table 4.11-25 provides an overview of the potential percent change in economic value of electrical power generated for each action alternative relative to the No Action Alternative for the mean, median, 90th percentile, and 10th percentile values.

Table 4.11-25
Change in Headgate Rock Powerplant Total Economic Value of Electrical Power Generated (percent)

Action Alternative	Mean	Median	90th Percentile	10th Percentile
Basin States	(1.29)	(1.46)	(0.38)	(2.03)
Conservation Before Shortage	(2.02)	(2.12)	(0.46)	(3.78)
Water Supply	(0.17)	0.31	(0.76)	0.25
Reservoir Storage	(2.31)	(3.81)	1.29	(4.65)
Preferred Alternative	(1.83)	(2.23)	(0.48)	(3.67)

In general, the value of electrical power generated under the Water Supply Alternative could potentially be slightly higher than under the No Action Alternative. The value of electrical power generated under the Basin States, Conservation Before Shortage, and Reservoir Storage alternatives, and the Preferred Alternative could potentially be less than under the No Action Alternative.

Currently Headgate Rock Powerplant generates more electrical power than is needed by CRIT. Implementation of any of the action alternatives is not expected to impact Headgate Rock Powerplant's ability to meet CRIT's current electrical power demands. However, a reduction in Headgate Rock Powerplant generation could impact BIA's ability to meet new Tribal energy demands.

4.11.2.5 Basin Power Funds

Upper Colorado River Basin Fund. Approximately $175 million is needed each year to fund Reclamation and Western operating needs. Western is responsible for transmission and marketing of CRSP power, collecting payment for the power, and the transfer of revenues for repayment to the General Treasury.

Implementation of the various alternatives will likely result in more variation in the Basin Fund, 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. Western and its power customers need to quickly respond to changing hydrological conditions to forestall possible financial problems.

In addition, if an alternative were to increase or decrease Glen Canyon Powerplant electrical power generation over an extended period of time, Western and its power customers might decide to increase or decrease allocations in response, which could, in turn, affect the rate Western charges for the power and its financial reserves in the Basin Fund. A rate increase could affect customers' generation and power purchase decisions as well as their overall financial condition.

An important aspect associated with power delivery is whether and how much one or more of the alternatives alters the probability of a total loss of generation from Glen Canyon Powerplant. Loss of Glen Canyon Powerplant generation would result in a loss of revenue to Western, Reclamation, and various environmental programs in the Upper Basin; loss of generation and replacement costs for power customers; and degradation to power system reliability.

In the cases of such a loss of power, potential mitigation measures may need to be evaluated to offset or replace power revenue reductions and impacts to the Basin Fund and programs supported by this fund. A significant portion of the annual funding of the Endangered Fish Recovery Implementation Program is provided by power revenues. As such, any significant reduction in the power revenues would require that funds be secured from other sources.

Figure 4.11-6 shows the percentage of Lake Powell end-of-March elevations from Reclamation's CRSS modeling output that are less than or equal to elevation 3,490 feet msl. March typically has the lowest Lake Powell reservoir elevation of the year and elevation 3,490 feet msl is the point at which electrical power can no longer be produced at the Glen Canyon Powerplant. Using this measure, the Water Supply Alternative is more likely to provide conditions that would result in Lake Powell elevations falling below the minimum power pool elevation of 3,490 feet msl, as compared to the No Action Alternative. The Reservoir Storage, Basin States, and Conservation Before Shortage alternatives, and the Preferred Alternative have equal or slightly lower probabilities than the No Action Alternative. An analysis of end-of-July elevations indicated that these values are less pronounced than the end-of-March elevations, but similar.

Lower Colorado River Basin Development Fund. The functions of the Development Fund are to collect revenues and repayment associated with CAP, and to fund expenses related to the Colorado River Basin Salinity Control Program and projects as directed by the Arizona Water Rights Settlements Act (Public Law 108-451).

An important aspect associated with power delivery is whether and how much one or more of the alternatives alters the probability of a total loss of generation from Hoover Powerplant. Loss of Hoover Powerplant generation would result in a loss of revenue to Western, Reclamation and various environmental programs in the Lower Basin; loss of generation and replacement costs for power customers; and, degradation to power system reliability.

Figure 4.11-7 shows the percentage of end-of-July elevations from Reclamation's CRSS modeling output that are less than or equal to elevation 1,050 feet msl. This elevation is the point at which it is currently assumed that power can no longer be produced at the Hoover Powerplant.

Figure 4.11-6
Lake Powell End-of-March Elevations
Comparison of Action Alternatives to No Action Alternative
Percent of Values Less Than or Equal to Elevation 3,490 feet msl

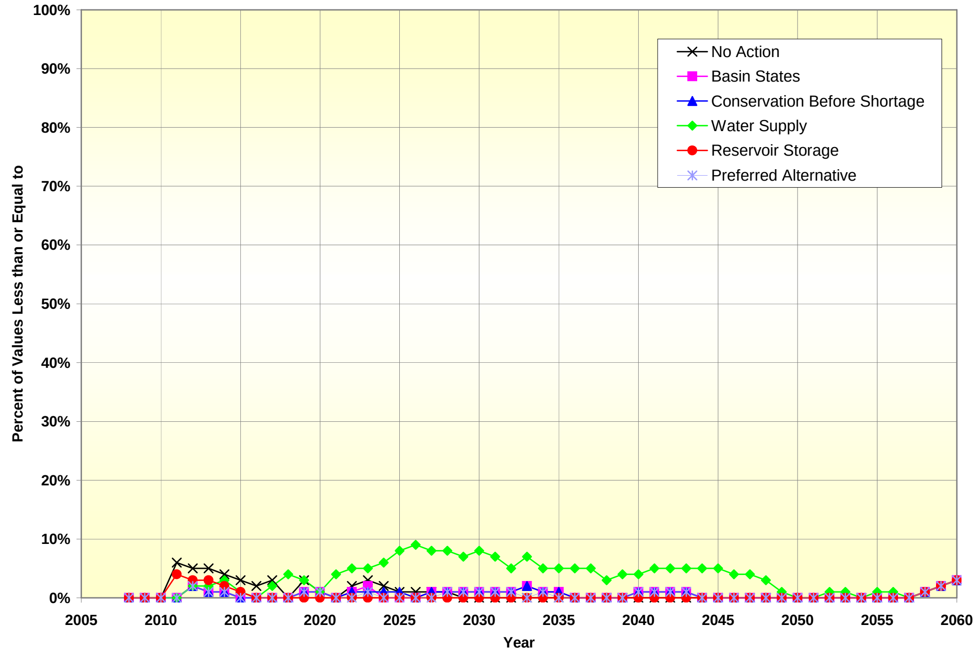
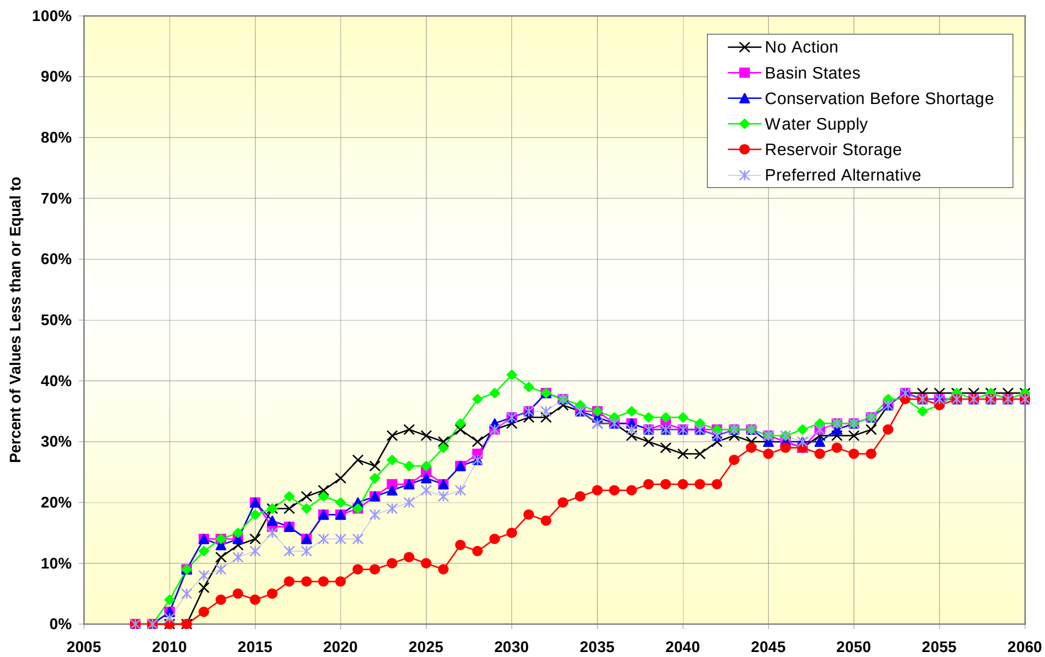


Figure 4.11-7
Lake Mead End-of-July Elevations
Comparison of Action Alternatives to No Action Alternative
Percent of Values Less than or Equal to Elevation 1,050 feet msl



Using this measure, the Water Supply Alternative is slightly more likely to produce conditions that would result in Lake mead elevations falling below the minimum power pool elevation of 1,050 feet msl than the No Action Alternative, while the Basin States and Conservation Before Shortage alternatives have equal or slightly lower probabilities than the No Action Alternative. The Preferred Alternative has slightly lower probability of having elevations below the power pool elevation through 2028, while the Reservoir Storage Alternative has much lower probability of having elevations below the power pool elevation. Values for end-of-July Lake Mead elevations are less pronounced, but similar.

Any of the alternatives that reduce electrical power production would reduce the surcharge revenues available to defray costs associated with the Colorado River Basin Salinity Control Act (Title II) and the CAP repayment.

Colorado River Dam Fund. The Dam Fund is utilized to fund operation and maintenance payments to states, visitor services, up-rating program, replacements, investment repayment, and interest expenses of the Boulder Canyon Project. The annual revenue requirement is typically approximately $60 to $70 million per fiscal year.

Since implementation of the various alternatives could result in more variation in the Dam Fund cash reserves, this could lead to additional actions such as power rate adjustments, or reductions to contractors allocations to respond to shortfalls in capacity, energy and revenues under dry conditions.

4.11.2.6 System-Wide Electrical Power Issues

Conservation Before Shortage Surcharge. The Conservation Before Shortage proposal submitted to Reclamation (Appendix K) suggests that a portion of the funding for the proposed voluntary conservation program could be derived from a conditional surcharge on power rates under existing or renewed contracts for hydropower produced at Hoover Dam. It is suggested that this surcharge could be imposed in years when Reclamation’s August 24-month study projects that storage in Lake Mead falls below 50 percent of its active capacity. The revenues generated by this surcharge could be collected in a power pool protection fund, to be maintained by Reclamation for expenditure when and if lake elevations reach a conservation trigger.

This surcharge is not included in the current economic analysis at any of the Upper or Lower Basin facilities or Basin Funds. Surcharges imposed are typically not included within Western's or Reclamation's electrical power rate structure. For example, the current 4.5 mil and the 2.5 mil rate imposed on Hoover Powerplant, and Parker and Davis Powerplant power contractors to help repay Reclamation’s CAP project construction costs and to provide funding for salinity projects are a separate part of the contractor’s bill.

Imposing a surcharge on power revenues would require separate legislation. Rate-making authority, except for Reclamation's project use power, lies with Western, therefore such changes would be under the purview of the Secretary of the Department of Energy and the United States Congress.

Ancillary Service Impacts. In addition to generating electrical power, each of the power generation facilities in the study area provides other electrical products and services referred to as ancillary services. Ancillary services are those services necessary to keep the power grid functioning continuously, safely, and reliably.

Western, as an operator of multiple control areas (referred to also as balancing authorities), is required by the Federal Energy Regulatory Commission to offer ancillary services to entities purchasing transmission services in its control areas. Entities purchasing transmission are required to self-supply ancillary services or purchase ancillary services from third parties. Hoover Powerplant capacity and energy is dynamically scheduled and made available to the contractors which allows certain ancillary services to be utilized in other control areas. The Hoover Powerplant is also a significant source of reserves, regulation and frequency control for non-Western control areas in Arizona, California, and Nevada.

Reserves. Because of low load factors at the Glen Canyon Powerplant and Hoover Powerplant, at any given time there are hundreds of megawatts of spinning or supplemental reserves that can be called on to respond to generating unit outages and power system emergencies. The available unscheduled capacity at the Parker and Davis Powerplants is used primarily for reserves. In addition, the generation units at Davis Powerplant have a portion of their capacity used exclusively for reserves.

Action alternatives that reduce or eliminate capacity at the Glen Canyon Powerplant and Hoover Powerplant will reduce or eliminate reserve capacity as well, impacting reliability of the power system, and impacting revenue to Western or to specific projects. None of the alternatives are expected to have a significant impact on reserves at the Parker and Davis Powerplants since the associated reservoir elevations are not affected. A reduction in electrical power production at these powerplants would create a slight increase in the average reserve capacity available.

Regulation and Frequency Control. Regulation and frequency control is needed to maintain power system stability and the moment-to-moment balance between load and generation. Reductions in electrical power generation from the Glen Canyon Powerplant and Hoover Powerplant would impact the ability of these powerplants to provide regulation services. Although the generating units are able to regulate throughout most of their operating range, the amount of regulation available decreases as generating capability decreases.

The Hoover Powerplant is primarily used to provide regulation for the control area. However, the Davis Powerplant has some capability for regulation and frequency control, but the available unscheduled capacity at the Davis Powerplant is used almost exclusively for reserves.

Any of the alternatives that cause the Glen Canyon Powerplant or Hoover Powerplant to stop generating completely due to low reservoir elevation (below the minimum power pool elevation), could potentially eliminate regulation as well. As shown on Figures 4.11-6 and 4.11-7, the Water Supply Alternative poses the greatest risk to regulation and frequency control at the Glen Canyon Powerplant and Hoover Powerplant, respectively.

Reactive Supply and Voltage Control. Reactive power is power required to charge the transmission lines and associated electrical equipment that comprise the power grid. Unlike other ancillary services that can assist the power system over large geographical areas, reactive supply and voltage control are limited to small areas. The Glen Canyon Powerplant supplies reactive power to northern Arizona and southern Utah, and the Hoover Powerplant supplies reactive power to northwestern Arizona, Southern Nevada, and southeastern California. Without an adequate supply of reactive power and constant monitoring, power system voltages can increase or decrease beyond acceptable limits, leading to system instability, cascading outages, and damage to electrical equipment.

Black Start Capability. Black Start Service, also referred to as Startup Service consists of providing the electrical power needed to start up a generating plant, usually after a system emergency (e.g., large scale blackout) that causes loss of electricity from the generating station.

The Glen Canyon Powerplant is relied upon to provide Black Start Service capability to the power system. The Hoover Powerplant is relied upon to provide the same capability to the power system and also for Palo Verde Nuclear Generating Station located outside Phoenix, Arizona. Similar to regulation and frequency control, the Water Supply Alternative is most prone to cause Glen Canyon Powerplant and Hoover Powerplant to stop generating completely due to low reservoir elevation conditions. The Parker and Davis Powerplants do not provide Black Start Service.

Contract Commitments. Western contracts with preference power customers to supply firm energy and capacity. Currently, about 243 municipalities, rural electric cooperatives, Indian tribes, irrigation districts, and state and federal facilities in Arizona, Nevada, New Mexico, Colorado, Utah, and Wyoming are served from SLCA/IP power facilities, which includes the Glen Canyon Powerplant. The Hoover Powerplant contractors have an allocation from Western for a specific quantity of contingent capacity and associated firm energy.

At the Glen Canyon Powerplant, the current contracts went into effect in October 2004 and extend through September 2024. At the Hoover Powerplant, the current contracts went into effect in June 1987 and extend through September 2017. For the Parker and Davis Powerplants, current contracts went into effect in October 1988 and extend through September 2008.

Each contractor has an allocation from Western for a specific quantity of energy and capacity each month. Western guarantees that the minimum quantity of energy will be available for contractors, and purchases power to meet that level whenever hydropower generation is insufficient to supply the required amount (referred to as firming purchases). Hydropower generation above the minimum level is also allocated to contractors on an as-available basis as operational and hydrological conditions allow.

An alternative may increase or decrease energy generation and capacity at the Glen Canyon Powerplant or Hoover Powerplant. Western has the ability to modify its contract commitments to its electrical power customers when a change in the volume of water released at these dams results in changes in electrical generation and capacity. For example, if an alternative reduces energy generation and capacity at the Glen Canyon Powerplant over the long-term average, Western would have the ability to lower its contract commitments to those customers who have contracts that include Glen Canyon Powerplant electrical power. The lower commitments would cause these customers (electrical utilities) to add new generating facilities, speed up planned construction of new generating facilities or take other action to make up for the reduction in Western's contract commitment. The estimated values of these actions by customers are what is portrayed in the tables in this section.

Energy and capacity allocations to contractors can be revised when the contracts are renewed. Allocations to contractors after contract terms expire will depend upon projections of future capacity and energy.

4.11.2.7 Electrical Power Use Associated with Water Supply Systems

This section discusses potential changes in pumping costs for the following entities that pump water from reservoirs: the NGS which obtains cooling water from Lake Powell; the City of Page which obtains municipal water from Lake Powell; SNWA which obtains water from Lake Mead; and CAP and MWD which pump water from Lake Havasu. Incremental differences in pumping costs are associated with differences in modeled average Lake Powell, Lake Mead, and Lake Havasu elevations between the No Action Alternative and the action alternatives.

River system modeling provided the average elevations for Lake Powell, Lake Mead, and Lake Havasu under the No Action Alternative and the action alternatives. Increases or decreases in net effective pumping head correspond with decreases or increases in average reservoir elevations. Estimates of the differences in pumping costs were calculated using these changes in pumping head, as well as estimates of annual pumping volumes, unit electrical power costs and pump efficiency.

Navajo Generating Station. The SRP estimates that water use at NGS will be approximately 29,000 afy in the future. Power for the intake pumps is obtained from auxiliary power units at NGS at a cost of $0.0104 per kWh. Table 4.11-26 identifies changes in electrical power requirements for the alternatives and the associated increase or decrease in cost.

Table 4.11-26
Change in Navajo Generating Station Intake Electrical Power Requirements at Lake Powell [1]

Action Alternative	Change in Annual Electrical Power Requirement (kWh)[2]	Change in Associated Annual Cost ($)
Basin States	122,484	1,170
Conservation Before Shortage	107,701	1,120
Water Supply	307,748	3,201
Reservoir Storage	(102,580)	(1,067)
Preferred Alternative	84,684	881

1. *Assumes 29,000 afy of pumping; Cost = E (kWh) = $0.0104*
2. *E (kWh) = 1.024 * V (afy) * H (ft) / E (%)*

City of Page Water Supply. The average annual water demand by the City of Page in recent years has been around 2,650 af (Section 3.12). Annual electrical power demand to deliver the water has averaged around 3,900,000 kWh per year over the past 10 years. Under the No Action Alternative, using the current rate of $.03286 per kWh (includes overhead), the annual cost of electrical power for pumping the water is around $130,000 per year.

Table 4.11-27 summarizes the differences in pumping costs for the Reclamation-operated raw water intake serving the City of Page. The greatest increase would occur under the Water Supply Alternative, an average increase of about $919 per year, in comparison to the No Action Alternative total annual cost of $130,000, an approximate increase of less than one percent. In general the effect on City of Page pumping costs would be minor under all alternatives.

Table 4.11-27
Change in City of Page Intake Electrical Power Requirements at Lake Powell [1]

Action Alternative	Change in Annual Electrical Power Requirement (kWh)[2]	Change in Associated Annual Cost ($)
Basin States	10,280	336
Conservation Before Shortage	9,842	322
Water Supply	28,122	919
Reservoir Storage	(9,374)	(306)
Preferred Alternative	7,738	253

1. *Assumes 2,650 afy of Pumping; Cost = E (kWh) = $0.03286*
2. *E (kWh) = 1.024 * V (afy) * H (ft) / E(%)*

SNWA Water Supply. Under the No Action Alternative, the average Lake Mead elevation declines from 2007 through 2060. The chance that lake elevations could drop below the minimum power pool elevation of 1,050 feet msl increases for all alternatives, with the Reservoir Storage Alternative resulting in the smallest increase in probability. These results also suggest that under the No Action Alternative, SNWA can expect pumping costs to increase due to the increase in net effective pumping head. The cost of pumping varies with each of the action alternatives as an increase or decrease compared to the No Action Alternative. Table 4.11-28 shows the potential differences between pumping costs under the action alternatives to those under the No Action Alternative.

Table 4.11-28
Change in Estimated SNWA Pumping Costs

Action Alternative	Change in Cost ($)
Basin States	(22,780)
Conservation Before Shortage	(38,726)
Water Supply	227,803
Reservoir Storage	(2,144,115)
Preferred Alternative	(501,720)

The change in pumping costs shown in Table 4.11-28 considers the difference in the average of the 50th percentile (median) Lake Mead annual elevation values from 2008 to 2060 under each action alternative to that of the No Action Alternative. The differences in the average of the median elevations (between each action alternative and the No Action Alternative) was multiplied by the estimated annual SNWA combined pumping costs for the two SNWA intake pump stations (Levy 2006 personal communication) corresponding to the respective Lake Mead elevations. A positive number in Table 4.11-28 indicates an increase in annual SNWA pumping costs and a negative number (in parenthesis) indicates a potential savings in annual SNWA pumping costs when compared to pumping costs required under the No Action Alternative.

CAP Pumping Load. Under all alternatives, when shortages are imposed on the CAP, there is an associated reduction in electrical power requirements to pump water, and more of CAP’s share of NGS generation is available to be marketed (after 2011). For a 500,000 af shortage (at $48/MWh), the annual market value of the electrical power available to be marketed is approximately $41 million.

This revenue would benefit all CAP users to the extent it would be used to offset CAWCD’s repayment obligation, as well as Indian tribes that benefit from the AWSA. The Reservoir Storage Alternative would result in the greatest overall shortages, and therefore the greatest reduction in CAP pumping load. Increased power revenues on the CAP water would likely be offset by increased delivery charges to CAP water users when CAP deliveries are reduced because of shortages.

4.11.2.8 Summary Comparison of Alternatives

Tables 4.11-29, 4.11-30, 4.11-31, and 4.11-32 summarize effects of each of the action alternatives compared to the No Action Alternative for electrical energy generation, generation capacity, and associated economic effects for the Glen Canyon, Hoover, Parker and Davis, and Headgate Rock Powerplants.

Table 4.11-29
Glen Canyon Powerplant
Summary Comparison of Action Alternatives to No Action Alternative
Mean Values for Electrical Energy Generation, Generation Capacity, and Economic Value

	Action Alternative					
	No Action	Basin States	Conservation Before Shortage	Water Supply	Reservoir Storage	Preferred Alternative
Annual Energy Generation (MWh)	4,247,880	4,244,270	4,244,890	4,138,760	4,281,050	4,251,340
Change in Annual Energy Generation (MWh)	0.0	(3,610)	(2,990)	(109,120)	33,170	3,460
Change in Annual Energy Generation (percent)	0.0	(0.08)	(0.07)	(2.57)	0.78	0.08
Monthly capacity (MW)	606	605	605	589	611	606
Change in Monthly Capacity (MW)	0.0	(1)	(1)	(17)	5	0
Change in Monthly Capacity (percent)	0.0	(0.15)	(0.13)	(2.72)	0.79	0.0
Economic Value of Electrical Power Generation – Total (PV 2008 $ million)	7,350	7,352	7,353	7,184	7,415	7,364
Change in Present Value of Electrical Power Generation (PV 2008 $ million)	0.0	2	3	166	65	14
Change in Present Value of Electrical Power Generation (percent)	0.00	0.02	0.04	(2.25)	0.88	0.19

Table 4.11-30
Hoover Powerplant
Summary Comparison of Action Alternatives to No Action Alternative
Mean Values for Electrical Energy Generation, Generation Capacity, and Economic Value

	Action Alternative					
	No Action	Basin States	Conservation Before Shortage	Water Supply	Reservoir Storage	Preferred Alternative
Annual Energy Generation (MWh)	3,127,523	3,120,563	3,125,979	3,052,877	3,411,336	3,171,295
Change in Annual Energy Generation (MWh)	0	(6,960)	(1,544)	(74,646)	283,813	43,772
Change in Annual Energy Generation (percent)	0.0	(0.22)	(0.05)	(2.39)	9.07	1.40
Monthly capacity (MW)	1,191	1,195	1,198	1,160	1,328	1,219
Change in Monthly Capacity (MW)	0.0	4	7	(31)	137	28
Change in Monthly Capacity (percent)	0.0	0.31	0.58	(2.56)	11.52	2.31
Economic Value of Electrical Power Generation – Total (PV 2008 $ million)	7,223	7,229	7,247	7,042	7,991	7,395
Change in Present Value of Electrical Power Generation (PV 2008 $ million)	0.0	6	24	(181)	768	172
Change in Present Value of Electrical Power Generation (percent)	0.0	0.08	0.34	(2.51)	10.63	2.38

Table 4.11-31
Parker and Davis Powerplant
Summary Comparison of Action Alternatives to No Action Alternative
Mean Values for Electrical Energy Generation, Generation Capacity, and Economic Value

	Action Alternative					
	No Action	Basin States	Conservation Before Shortage	Water Supply	Reservoir Storage	Preferred Alternative
Annual Energy Generation (MWh)	1,639,687	1,630,499	1,628,324	1,641,424	1,622,209	1,628,473
Change in Annual Energy Generation (MWh)	0	(9,188)	(11,363)	1,737	(17,478)	(11,214)
Change in Annual Energy Generation (percent)	0.0	(0.56)	(0.69)	0.11	(1.07)	(0.68)
Monthly capacity (MW)	331	331	331	331	331	331
Change in Monthly Capacity (MW)	0	0	0	0	0	0
Change in Monthly Capacity (percent)	0.0	0.0	0.0	0.0	0.0	0.0
Economic Value of Electrical Power Generation – Total (PV 2008 $ million)	2,268	2,256	2,251	2,275	2,233	2,250
Change in Present Value of Electrical Power Generation (PV 2008 $ million)	0.0	(12)	(17)	7	(35)	(18)
Change in Present Value of Electrical Power Generation (percent)	0.0	(0.53)	(0.73)	0.31	(1.54)	(0.81)

Table 4.11-32
Headgate Rock Powerplant
Summary Comparison of Action Alternatives to No Action Alternative
Mean Values for Electrical Energy Generation, Generation Capacity, and Economic Value

	Action Alternative					
	No Action	Basin States	Conservation Before Shortage	Water Supply	Reservoir Storage	Preferred Alternative
Annual Energy Generation (MWh)	77,482	76,548	76,160	77,266	76,163	76,318
Change in Annual Energy Generation (MWh)	0	(934)	(1,322)	(216)	(1,319)	(1,164)
Change in Annual Energy Generation (percent)	0.0	(1.21)	(1.71)	(0.28)	(1.70)	(1.50)
Monthly capacity (MW)	331	331	331	331	331	331
Change in Monthly Capacity (MW)	0	0	0	0	0	0
Change in Monthly Capacity (percent)	0.0	0.0	0.0	0.0	0.0	0.0
Economic Value of Electrical Power Generation – Total (PV 2008 $ million)	103	102	101	103	101	101
Change in Present Value of Electrical Power Generation (PV 2008 $ million)	0.0	(1)	(2)	(0.2)	(2)	(2)
Change in Present Value of Electrical Power Generation (percent)	0.0	(1.29)	(2.02)	(0.17)	(2.31)	(1.83)

Glen Canyon and Hoover Powerplants. Tables 4.11-29 and 4.11-30 presents potential changes in generation, capacity, and economic value of electrical power. The Basin States, Conservation Before Shortage, and Water Supply alternatives, and the Preferred Alternative result in minor variations for each of these parameters. The Water Supply Alternative would have the greatest adverse effect on electrical power production and value because of generally lower elevations. Most of these changes are less than one percent, however, and these alternatives result in both positive and negative variations. Therefore, these impacts are considered minor. The Reservoir Storage Alternative generally results in greater positive changes with respect to electrical power production and value because of higher reservoir elevations and would result in moderate beneficial effects, particularly in the case of the Hoover Powerplant.

Parker, Davis, and Headgate Rock Powerplants. These facilities are generally considered to be "run of the river" electrical power generation facilities and are affected primarily by release volumes from Hoover Dam. As presented in Tables 4.11-31 and 4.11-32, the Basin States, Conservation Before Shortage, and Reservoir Storage alternatives, and the Preferred Alternative, all generally result in minor decreases in electrical power production and value at these facilities as compared to the No Action Alternative because they result in lower release volumes downstream of Hoover Dam, with the Reservoir Storage Alternative having the greatest adverse effects. Again, these changes are relatively minor (most less than one percent). The Water Supply Alternative results in greater release volumes downstream and therefore slight increases in electrical power production and value as compared to the No Action Alternative. These increases are considered beneficial but also minor as compared to overall electrical power production at these facilities.

Water Supply Systems. As presented in Table 4.11-29, the Basin States, Conservation Before Shortage, and Water Supply alternatives, and the Preferred Alternative would generally result in lower elevations at Lake Powell, as compared to the No Action Alternative, and therefore could potentially result in increased pumping costs for NGS and City of Page, with the Water Supply Alternative resulting in approximately twice the increase in costs as compared to the other action alternatives.

At Lake Mead, all of the action alternatives, with the exception of the Water Supply Alternative, provide higher reservoir elevations as compared to the No Action Alternative and therefore could potentially provide a decrease in pumping costs. As presented in Table 4.11-28 the Water Supply Alternative could potentially increase pumping costs.

The Reservoir Storage Alternative would result in generally higher reservoir elevations and therefore reduced pumping costs as compared to the No Action Alternative. This beneficial effect is also considered minor.

Basin Power Funds. Reductions in power revenues could reduce the amount of money available to meet the intended uses of these funds, possibly leading to reductions in allocations to power contractors or power rate adjustments. The action alternatives generally have a minor impact on the economic value of electrical power generation at the Glen Canyon and Hoover Powerplants. However, total loss of electrical power generation capabilities would have a substantial effect on the basin power funds. At the Glen Canyon Powerplant, the probability of this type of loss in electrical power generation capability is very small (less than five percent) except under the Water Supply Alternative, which would result in as much as a nine percent probability. At Hoover Powerplant, the probability of total loss of generation is higher, increasing from the current negligible probability to about 30 percent in 2026. However, as shown in Figure 4.11-7, the Reservoir Storage Alternative is the exception to this, while the remaining alternatives are very similar to the No Action Alternative.

4.12 Recreation

This section discusses the recreational resources within the study area that may be affected by the proposed federal action. The potentially affected recreational resources include:

- shoreline public use facilities;
- reservoir boating;
- river and whitewater boating; and
- sport fishing.

4.12.1 Methodology

The following methods were used to determine the effects of the alternatives on recreational resources.

4.12.1.1 Method Used to Assess Shoreline Public Use Facilities

These sections examine the probabilities that reservoir elevations would decrease below critical thresholds for use of selected marinas, boat docks, and boat launch ramps. These sections also assess whether impacts would occur in access to or use of attraction features. Threshold reservoir elevations were determined by reviewing published sources and through personal communication with Reclamation, NPS, and resource specialists, and from public comments provided during scoping for this EIS. The threshold elevations were used as indicators of recreational facilities that might be rendered inoperable or require relocation or modification to maintain their operation. Projections of reservoir elevations for 2008, 2016, 2026, 2030, 2040, 2050, and 2060 are provided in Section 4.3. The narrative of effects of the alternatives is provided below for selected facilities in July or September, representing relatively high visitation months for both Lake Powell and Lake Mead. These facilities are representative of potential effects of the alternatives on shoreline recreation opportunities at each reservoir. Results are presented for 2026, representing the end of the interim period. For Lake Powell, Wahweap Marina was selected for description in the narrative due to its popularity with boaters. For Lake Mead, Pearce Ferry at the inflow area to the reservoir is described. Effects on Echo Bay public launch ramp are also described in the narrative because it represents a facility that closes at the relatively low reservoir elevation of 1,050 feet msl.

4.12.1.2 Method Used to Assess Reservoir Boating

This analysis assesses the probabilities of reservoir elevations decreasing below critical thresholds, resulting in boating navigation hazards, changing navigable areas, and passage ways, and assesses whether corresponding decreases in reservoir surface areas might affect safe boating capacities. Threshold pool elevations were determined by reviewing published sources and through personal communication with Reclamation, NPS, and resource specialists, and from public comments.

In general, the surface area of the reservoirs available for boating is reduced when the reservoir elevation drops, which may affect the number of boats that can safely operate at one time, referred to as safe boating density. The safe boating density value can be used to assess the effects of each alternative on boating safety if levels of daily boating use were available. However, recent and consistent information on the level of daily or peak boating use, such as whether the current boating densities on the reservoirs have approached or exceeded the safe boating density is not available. Without information on current reservoir boating densities, it cannot be determined whether any reductions in pool elevations at Lake Powell and Lake Mead associated with the alternatives would result in unsafe boating conditions due to a corresponding increase in boating density. Personal communications with boaters and NPS managers suggest that Lake Mead and Lake Powell have not exceeded safe boating densities.

Navigation hazards and shallow waters require boaters to take detours around inaccessible areas. This may add mileage to trips and may influence recreational boaters to remain in specific areas, which can result in congestion in those areas. Additionally, as reservoir elevations drop and surface area decreases, congestion may become more noticeable in popular areas that receive high-use or where narrow travel corridors exist.

4.12.1.3 Method Used to Assess River and Whitewater Boating

This analysis uses river flow data from Section 4.3 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 to the No Action Alternative. Whitewater boating is the key recreational activity in Grand Canyon downstream of Lees Ferry and upstream of Lake Mead. Other river reaches do not provide whitewater boating opportunities and, therefore, are not addressed in this EIS.

Threshold river flows were determined by reviewing published sources and through personal communication with river managers and from comments received during scoping. These representative river flows were chosen as indicators for whitewater boating safety and the availability of rest areas and take-out points.

This 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.

4.12.1.4 Method Used to Assess Sport Fishing

This analysis evaluates changes in sport fishing opportunities by river reach under the action alternatives as compared to the No Action Alternative. The assessment of sport fishing was based on literature review to determine the current status of fish assemblages in the study 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 to 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 its 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 sports fish and threadfin shad are their food source. Striped bass feed on threadfin shad, and when shad are abundant, striped bass are able to reproduce and grow quickly. The resulting increased bass population continues feeding on the threadfin shad, and they deplete the shad populations. As striped bass decline in numbers predation on threadfin shad decreases. This causes the threadfin shad population to increase again. This cycle has been occurring since the first introduction of striped bass into Lake Powell in 1974 and is expected to continue in the future (Gustaveson 1999).

Rainbow trout and its water temperature thresholds were used to analyze potential differences in impacts between the alternatives downstream of Glen Canyon Dam. Minimum, maximum, and lethal water temperatures for various life history stages were determined and the months during which spawning, incubation, and growth occur were established. The 10^{th} percentile data were used to analyze potential effects because the 50^{th} and 90^{th} percentile data are essentially identical between the alternatives and no meaningful differences exist. It is important to note that the 10^{th} percentile elevations are unlikely to occur in any given year or consistently over time (Section 4.2). Modeled temperature data at Glen Canyon Dam and Lees Ferry, the Little Colorado River confluence, and at Diamond Creek were used in the trout fishery analysis. A qualitative analysis of potential water temperature changes and effects on rainbow trout were made by comparing the differences between water temperatures under the No Action Alternative and the action alternatives.

Water Temperature Assessment. Minimum and maximum monthly surface water temperature data (up to ten feet below the surface) for Lake Powell were provided and compared to striped bass and threadfin shad thresholds to determine whether potential surface water temperatures would exceed the lethal tolerances of striped bass or threadfin. The lower lethal limit for striped bass is 5°C and the upper lethal limit is 33°C. The lower lethal limit for threadfin shad is 5°C and the upper lethal limit is 37°C.

Modeled river water temperatures (Section 4.5 and Appendix P) were used to assess the possible effects on rainbow trout in the river reach from Glen Canyon Dam to Diamond Creek (Tables 4.5-4 to 4.5-9 and Appendix P). Conditions supporting rainbow trout spawning and incubation were assumed to deteriorate as temperature of river water warms beyond 15ºC (Table 4.12-1). Trout eggs that are subjected to temperatures warmer than 15ºC are prone to increased mortality (Table 4.12-1). Juvenile rearing success is assumed to deteriorate at water temperatures ranging from 17ºC to 25ºC. Rainbow trout can be expected to show significant mortality at temperatures exceeding 25ºC (Myrick and Cech 2001; Raleigh et al. 1984) (Table 4.12-1).

Table 4.12-1
Water Temperature Tolerances of Rainbow Trout (ºC)

Species	Species Code	Spawning			Incubation			Growth			Lethal	
		Minimum	Maximum	Optimum	Minimum	Maximum	Optimum	Minimum	Maximum	Optimum	Low	High
Rainbow Trout	RBT	8	13	10	7	15	10	12	21	16	0	25

In the Colorado River, rainbow trout are year-round residents. Spawning typically begins in January and continues into May, with peak spawning occurring in March and April (Korman et al. 2005) (Table 4.12-2). During spawning, the female digs a redd (i.e., gravel nest) where the eggs are deposited, and they are then fertilized by the male. The optimal water temperature for trout spawning and incubation has been reported to fall between 7ºC and 15ºC (Table 4.12-1). Incubation lasts from 1.5 months to 4 months, depending on water temperature (Table 4.12-2).

Newly emerged fry move to shallow, protected areas along stream banks, but as they grow, they move to faster, deeper areas of the river. Shallow riffles are the most important channel type for trout during their first year (Barnhart 1986). Juvenile trout generally use riffles and runs in the main and secondary channels, along with the head and tail of pools. Juvenile rearing success is assumed to deteriorate at water temperatures ranging from 17ºC to 25ºC. Juvenile trout feed on a variety of aquatic and terrestrial insects and other small invertebrates.

Table 4.12-2
Life History of the Rainbow Trout, Phases by Months

Phases	Citations	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Spawning	2,4,5	■	■	■	■	■							
Egg Incubation	2,4,5	■	■	■	■	■	■	■	■				
Juvenile Rearing	2,4,5	■	■	■	■	■	■	■	■	■	■	■	■
Residence	1, 2, 3	■	■	■	■	■	■	■	■	■	■	■	■

1 *Lake Powell n.d. Available at: http://www.waterquality.utah.gov/watersheds/lakes/LAKEPOWL.pdf. Accessed October 27, 2006.*

2 *GCDAMP (Glen Canyon Dam Adaptive Management Program). n.d. Lees Ferry trout fishery. Available at: http://www.pn.usbr.gov/keyresc/tf.html. Accessed October 27, 2006.*

3 *Fishing in Laughlin, Nevada. 2006. Available at: http://www.laughlinnevadaguide.com/fish.htm. Accessed October 27, 2006.*

4 *Valdez 1993. Non-native fishes of Grand Canyon. Available at: http://www.gcrg.org/bqr/6-4/fishes.htm. Accessed: October 27, 2006.*

5 *Korman et al. 2005.*

Salinity Assessment. Salinity levels were assessed downstream of Hoover Dam and it was determined that future salinity levels would not affect rainbow trout (Section 4.5). Striped bass are naturally a brackish to salt water species, so any slight increase in salinity should have no effect on striped bass or threadfin shad. Therefore this issue is not discussed further.

Flow Assessment. Flow reductions that occur outside of spawning periods of fish are expected to have minimal impacts on fish species because habitat is likely not a factor limiting their populations. Extreme reductions, however, could result in the loss of fish through stranding and reduction in water quality (e.g., dissolved oxygen, temperature). The abundance of sports fishes, however, would be expected to recover following flow reduction periods through natural reproduction and through augmentations under fish stocking programs.

Flow reductions during the spawning period could desiccate eggs or strand juvenile fish. Impacts on sport fishes are expected to be minimal because their populations are relatively large and would be expected to recover following reduced flow conditions through natural reproduction and through augmentations under fish stocking programs.

Given that releases from Glen Canyon Dam would remain within their historic range, it was concluded that changes in flow would not be a useful tool to analyze effects on sport fish in this reach of the river. The reaches downstream of Hoover Dam are also expected to continue with operations similar to historic conditions. Therefore, flow assessment was not used in this analysis.

4.12.2 Recreation at Lake Powell

Threshold elevations below which shoreline recreational facilities at Lake Powell could be affected are identified in Section 3.12, Table 3.12-3. Below these elevations, facility adjustments or capital improvements would be required, creating potential impacts on recreation at Lake Powell. The percentages of values less than or equal to these threshold elevations during the study period are presented in Section 4.3, Figures 4.3-3 through 4.3-11 and Tables 4.3-2 through 4.3-10.

4.12.2.1 Access or Use of Lake Powell Boating Facilities

No Action Alternative. In September 2026, there is a 16 percent chance that the boat launch ramp at Antelope Point marina, located at elevation 3,588 feet msl, would close or need to be modified. In September 2026, there is a seven percent chance that elevations will be less than 3,560 feet msl, resulting in the closure or modification of Wahweap and lower Bullfrog launch ramps. Section 4.3, Table 4.3-7 and Figure 4.3-8 provide data for all years and all alternatives.

Basin States and Conservation Before Shortage Alternatives. In September 2026, there is a 20 percent chance of Closing Antelope Point and a nine percent chance of closing Wahweap launch ramps and a 10 percent chance of closing lower Bullfrog launch ramp under these two alternatives, respectively.

Water Supply Alternative. In September 2026, there is a 35 percent chance of closing Antelope Point launch ramp and a 23 percent chance of closing Wahweap and lower Bullfrog launch ramps under this alternative.

Reservoir Storage Alternative. In September 2026, there is an eight percent chance of closing Antelope Point launch ramp or modifying it, and a three percent chance of closing Wahweap and lower Bullfrog launch ramps under this alternative.

Preferred Alternative. In September 2026, there is a 19 percent chance of closing Antelope Point launch ramp and an eight percent chance of closing Wahweap and lower Bullfrog launch ramps under this alternative.

4.12.2.2 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 Lake Powell elevation of 3,620 feet msl, hazardous obstructions result in NPS prohibiting boating around Castle Rock and Gregory Butte; data for all years and all alternatives are provided in Section 4.3, Table 4.3-5 and Figure 4.3-6.

No Action Alternative. In September 2026, there is a 28 percent chance NPS would have to prohibit boating around Castle Rock and Gregory Butte due to navigational hazards.

Basin States and Conservation Before Shortage Alternatives. In September 2026, there is a 36 percent and 35 percent chance of boating restrictions around Castle Rock and Gregory Butte under these two alternatives, respectively.

Water Supply Alternative. In September 2026, there is a 52 percent chance of boating restrictions around Castle Rock and Gregory Butte.

Reservoir Storage Alternative. In September 2026, there is a 24 percent chance of boating restrictions around Castle Rock and Gregory Butte.

Preferred Alternative. In September 2026, there is a 32 percent chance of boating restrictions around Castle Rock and Gregory Butte.

4.12.2.3 Lake Powell Sport Fish Populations

The maximum lethal limits of 37°C and 33°C for threadfin shad and striped bass, respectively, would not be exceeded under any of the alternatives. Further, these water temperatures are for the upper ten feet of the reservoir, and lower depths provide cooler water. It is assumed that striped bass and threadfin shad would be able to move into the cooler thermocline during the summer months (Gustaveson 1999). Water temperatures would not drop below the lower lethal limit of 5°C for striped bass or threadfin shad under any alternative. The coldest winter temperature could be 7°C. 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 to the reservoir sport fishery are not anticipated to occur under any of the alternatives.

The general trend for the alternatives indicates that Lake Powell elevations under the Basin States and Conservation Before Shortages alternatives, and the Preferred Alternative, do not differ substantially from the No Action Alternative. Therefore, Lake Powell sport fishing populations are expected to be similar to those under the No Action Alternative for lake sport fish under these three action alternatives. The Water Supply Alternative tends to have lower reservoir elevations, which makes the lake more susceptible to atmospheric temperature influence. The Reservoir Storage Alternative has generally higher Lake Powell elevations as compared to the No Action Alternative, which makes the lake less susceptible to atmospheric temperature influence. However, threadfin shad and striped bass should still be able to survive potential winter and summer temperature variations.

4.12.2.4 Access or Use of Rainbow Bridge

Above Lake Powell elevation of 3,650 feet msl, Rainbow Bridge is visible from the floating walkway and interpretive platforms at Rainbow Bridge National Monument. If Lake Powell elevations fall below 3,650 feet msl, Rainbow Bridge is no longer visible from the lake and the floating walkway and interpretive platforms are removed and stored. Under this circumstance, dock facilities would be moved to a lower elevation and connected to the land trail with a short walkway, and the old land trail through Bridge Canyon (submerged at full pool elevation) would be used. Reservoir elevation data for all years and all alternatives are provided in Section 4.3, Table 4.3-3 and Figure 4.3-4.

No Action Alternative. In September 2026, there is a 43 percent chance that NPS would have to close or modify facilities at Rainbow Bridge.

Basin States and Conservation Before Shortage Alternatives. In September 2026, there is a 58 percent and 57 percent chance that NPS would have to close or modify facilities at Rainbow Bridge under these two alternatives, respectively.

Water Supply Alternative. In September 2026, there is a 61 percent chance that NPS would have to close or modify facilities at Rainbow Bridge.

Reservoir Storage Alternative. In September 2026, there is a 39 percent chance that NPS would have to close or modify facilities at Rainbow Bridge.

Preferred Alternative. In September 2026, there is a 56 percent chance that NPS would have to close or modify facilities at Rainbow Bridge.

4.12.3 Recreation from Glen Canyon Dam to Lake Mead

4.12.3.1 Boating

Current operation of Glen Canyon Dam requires a minimum flow release of 8,000 cfs between 7 a.m. and 7 p.m., and 5,000 cfs at night. Therefore, daytime flows will not drop lower than the safe whitewater boating threshold flow of 5,000 cfs. In addition, flow releases from Glen Canyon Dam will be within the historical operating range. Releases from Glen Canyon Dam would generally be much higher than these minimum flows under all alternatives and hydrological conditions (Section 4.3, Tables 4.3-12 through 4.3-14). Therefore, there would be no change in exposure to unsafe boating conditions caused by change in river levels. Minor changes in exposure to boating navigation hazards caused by 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 ability to use sport fishing sites caused by change in flows, may occur under all alternatives. These changes would not be substantial and would not affect recreation use or opportunities.

4.12.3.2 Sport Fish Populations

Water temperature data from Lees Ferry, Little Colorado River confluence, and downstream of Diamond Creek gage were used for the Glen Canyon Dam to Lake Mead river reach to compare the No Action Alternative to the action alternatives (Tables P-BCR-1 to P-BCR-3 in Appendix P). Rainbow trout are the major sport fish in this Colorado River reach and they are therefore used for this assessment.

Glen Canyon Dam to Lees Ferry Reach:

- **No Action Alternative.** The historical range of release temperatures from Glen Canyon Dam was relatively stable between 1990 and 2002 and typically ranged from 7°C to 12°C (Section 4.8). These relatively stable cold temperatures were favorable for rainbow trout. Beginning in 2002, the range of release temperatures increased and the higher end of the range approached 16°C (Figure F-5 in Appendix F). Whirling disease was recently discovered in Lees Ferry trout. Research on whirling disease in other states indicates that water temperatures between approximately 10°C and 16°C appear to result in the highest prevalence of whirling disease infection (Montana Fish, Wildlife and Parks 1998). The intermediate host of the parasite that causes whirling disease is the tubifex worm. Water temperatures above and below the optimal range have been observed to reduce infection in trout. Under the No Action Alternative at the 10^{th} percentile, water temperatures have the highest potential to affect spawning, incubation, growth, and mortality of rainbow trout. Average temperatures at Lees Ferry will remain colder than the low end of the preference range for trout growth (less than 12°C) and within the historic range most of the time at Lees Ferry. In summer and fall months at the 10^{th} percentile release, average temperatures may exceed 12°C (Table P-BCR-1 in Appendix P). Average temperatures at Lees Ferry (Table P-BCR-1 in Appendix P) are always above the minimum suitable spawning temperature of 8°C (Table 4.12-1). The coldest months tend to be February, March, and April and average temperatures approach 8°C in these months, particularly at Lees Ferry. During potential egg incubation months of January through August, average temperatures may exceed the maximum temperature preference for incubation in August. Average temperatures at Lees Ferry are not expected to exceed 25°C but will be the warmest in summer and fall months at 10^{th} percentile releases. Temperatures under the No Action Alternative will continue to correspond with the optimal range for whirling disease in some months in the future, as has been occurring more frequently since 2002. However, temperatures could be both above and below the optimal range at certain times (Table P-BCR-1 in Appendix P). Since the parasite can persist in river sediments for a long time, temporary deviations from the ideal temperature range are not likely to result in eradication of this fish parasite once it is established in a particular river. Therefore, temperatures will continue to favor whirling disease downstream of Glen Canyon Dam into the future under the No Action Alternative. Overall, rainbow trout are expected to continue to persist downstream of Glen Canyon Dam under the No Action Alternative, though occasionally temperatures may be less than ideal for certain life history stages and parasites, as has occurred more often since 2002. Substantial impacts to the aquatic foodbase are not anticipated (Section 4.8).

- **Action Alternatives.** While the action alternatives as compared to the No Action Alternative are similar, the 10^{th} percentile water temperatures show a potential slight warming trend for all of the alternatives except the Reservoir Storage Alternative. Under the Reservoir Storage Alternative, the 10^{th} percentile average temperatures are above the minimum for growth (12°C) from July through November, which is similar to the No Action Alternative, though temperatures in these months remain lower than the No Action Alternative. The Water Supply Alternative shows the most potential warming but average water temperatures do not exceed the preferred growth temperature. Growth temperatures under the Basin States and Conservation Before Shortage alternatives, and the Preferred Alternative, are similar to those under the No Action Alternative. During the potential egg incubation period of January through August, the high end of the egg incubation temperature preference range (15°C) may be exceeded in July and August under the Basin States, Conservation Before Shortage, and Water Supply alternatives (Table P-BCR-1 in Appendix P). The Reservoir Storage Alternative, and the Preferred Alternative may exceeded incubation preferences in August. These higher average temperatures during the potential incubation period could cause egg mortality to a similar degree as under the No Action Alternative. The severity of egg mortality would depend on the duration of water temperatures above the limits for incubation, which is not known. Lethal limits for rainbow trout are not exceeded in any month for any action alternative. The Water Supply Alternative has the highest potential temperatures and thus may result in a shorter spawning season. Potential temperature effects on whirling disease under the Basin States and Conservation Before Shortage alternatives, and the Preferred Alternative, are similar to those under the No Action Alternative. The Water Supply Alternative has the warmest potential temperatures and could result in more often favorable conditions for whirling disease infection, though also a higher likelihood of temperatures too warm to favor whirling disease. The Reservoir Storage Alternative has the coldest temperatures and thus could be less likely to favor whirling disease infection. Substantial impacts to the aquatic foodbase are not anticipated (Section 4.8).

Little Colorado River Confluence:

- **No Action Alternative.** Under the No Action Alternative, the 10th percentile water temperatures were compared against the preferred water temperatures for spawning, incubation, growth and mortality of rainbow trout. From December through April average temperatures may be below the preferred ranges for growth (Table P-BCR-2 in Appendix P). Average temperatures are within the tolerance ranges for spawning during the spawning season and mortality for all months (Table P-BCR-2 in Appendix P). Average temperatures during the egg incubation period may exceed the temperature tolerance in July and August. Temperatures are within the ideal range for whirling disease in many months, though both warmer and colder than the ideal range sometimes. Conditions for whirling disease will be similar to those under the No Action Alternative for Lees Ferry.

- **Action Alternatives.** While the action alternatives as compared to the No Action Alternative are similar, the 10th percentile water temperatures show a slight potential warming trend for all of the alternatives except the Reservoir Storage Alternative, which is slightly cooler. The Water Supply Alternative shows the most potential warming and may exceed spawning temperatures in May (Table P-BCR-2 in Appendix P). Therefore, the Water Supply Alternative could potentially provide the shortest spawning season. Average temperatures under the remaining action alternatives remain suitable for spawning and are similar to those under the No Action Alternative, though the spawning season could be shortened in some years due to the warming trend of the remaining action alternatives. Warmer temperatures under the Water Supply Alternative would benefit trout growth, while the colder temperatures under the Reservoir Storage Alternative would reduce trout growth. The remaining action alternatives would result in growth conditions similar to those under the No Action Alternative. During the egg incubation period, the Basin States, Conservation Before Shortage, and Water Supply alternatives, and the Preferred Alternative, may exceed the egg incubation tolerance in June through August. The colder temperatures under the Reservoir Storage Alternative would only exceed this threshold in July and August. The severity of egg mortality would depend on the duration of water temperatures above the limits for incubation, which is not known. Lethal limits for rainbow trout are not exceeded in any month under any action alternative. Under all the action alternatives, temperatures are projected to be both within, above and below the ideal range for whirling disease. Temperature conditions for whirling disease under the Basin States and Conservation Before Shortage Alternatives, and the Preferred Alternative, are similar to those under the No Action Alternative. Temperature conditions for whirling disease under the Water Supply and Reservoir Storage Alternatives relative to the No Action Alternative are similar to the description for Lees Ferry, though the Reservoir Storage Alternative is above the ideal whirling disease range more often than others at Lees Ferry.

Diamond Creek:

- **No Action Alternative.** Under the No Action Alternative for Diamond Creek, the 10th percentile water temperatures show that from December through March average temperatures may be below the suitable range for growth. Higher average temperatures in May could exceed the temperature tolerance for spawning of 13°C (Table P-BCR-3 in Appendix P). Egg incubation temperatures may be exceeded in May through August and reduce reproductive success. Lethal water temperatures may be reached in the summer under the No Action Alternative though average temperatures remain below 25°C and it is anticipated that fish would be able to find thermal refugia.

- **Action Alternatives.** While the action alternatives as compared to the No Action Alternative are similar, the 10th percentile water temperatures show a potential warming trend for all of the alternatives, except for the Reservoir Storage Alternative. All of the action alternatives may meet or exceed spawning temperatures in April and May and exceed the egg incubation temperatures from May through August (Table P-BCR-3 in Appendix P). The Water Supply and Reservoir Storage Alternatives may potentially provide the shortest and longest spawning seasons, respectively, of the alternatives. The severity of egg mortality due to warmer temperatures would depend on the duration of water temperatures above the limit for incubation, which is not known. All of the action alternatives result in average temperatures from December through March that are below the threshold for trout growth, though similar to those under the No Action Alternative. The Basin States, Conservation Before Shortage, and Water Supply alternatives, and the Preferred Alternative, could result in average temperatures above the growth threshold (21°C) for trout in some months (Table P-BCR-3 in Appendix P). Overall, the Water Supply Alternative would result in the least favorable conditions for trout, while the Reservoir Storage Alternative would result in the best conditions. Lethal water temperatures above 25°C may be reached in July, August and September, though the average temperatures would remain below this threshold. These summer high temperatures would be greater than those under the No Action Alternative for these months except for the Reservoir Storage Alternative. However, juvenile and adult fish are able to find thermal refugia by moving upstream into cooler water habitats such as pools and may not be substantially affected by warmer water temperatures. Further, Diamond Creek is not as important for trout as Lees Ferry is.

4.12.4 Recreation at Lake Mead

Threshold elevations below which shoreline recreational facilities at Lake Mead could be affected are identified in Section 3.12, Table 3.12-7. Facility adjustments or capital improvements would be required below these elevations, creating potential impacts on recreation at Lake Mead. The percentages of values less than or equal to these thresholds during the study period are provided in Section 4.3, Figures 4.3-18 through 4.3-23 and Tables 4.3-18 through 4.3-23.

4.12.4.1 Access or Use of Lake Mead Boating Facilities

No Action Alternative. In July 2026, there is a 74 percent probability that Lake Mead elevations may be lower than 1,175 feet msl, resulting in the closure of the Pearce Bay launch ramp and the addition of another 16 miles that boaters would have to travel downstream to take-out (Section 4.3, Table 4.3-18 and Figure 4.3-18). The Echo Bay public launch ramp would close at elevation 1,050 feet msl (Section 4.3, Figure 4.3-22 and Table 4.3-22). In July 2026, there is a 30 percent chance that this facility would close under the No Action Alternative.

Basin States and Conservation Before Shortage Alternatives. In July 2026, there is a 76 and 75 percent chance of closing the Pearce Bay launch ramp under these two alternatives, respectively. In July 2026, there is a 23 percent chance under both of these alternatives that the Echo Bay public launch ramp would close due to low reservoir elevations.

Water Supply Alternative. In July 2026, there is a 78 percent chance of closing the Pearce Bay launch ramp. In July 2026, there is a 29 percent chance that the Echo Bay public launch ramp would close due to low reservoir elevations.

Reservoir Storage Alternative. In July 2026, there is a 66 percent chance of closing the Pearce Bay launch ramp and adding 16 miles to river trips. In July 2026, there is a nine percent chance that the Echo Bay public launch ramp would close.

Preferred Alternative. In July 2026, there is a 74 percent chance of closing the Pearce Bay launch ramp. In July 2026, there is a 21 percent chance that the Echo Bay public launch ramp would close.

4.12.4.2 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 elevation drops below 1,170 feet msl, there is no well-defined river channel in this upper portion of Lake Mead, making it dangerous for boaters (NPS 2005a).

No Action Alternative. In July 2026, there is a 73 percent probability that boaters may encounter navigational hazards in upper Lake Mead (Section 4.3, Figure 4.3-19 and Table 4.3-19).

Basin States and Conservation Before Shortage Alternatives. In July 2026, there is a 73 percent probability that boaters may encounter navigational hazards in upper Lake Mead.

Water Supply Alternative. In July 2026, there is a 76 percent probability that boaters may encounter navigational hazards in upper Lake Mead.

Reservoir Storage Alternative. In July 2026, there is a 64 percent probability that boaters may encounter navigational hazards in upper Lake Mead.

Preferred Alternative. In July 2026, there is a 72 percent probability that boaters may encounter navigational hazards in upper Lake Mead.

4.12.4.3 Sport Fish Populations

No Action Alternative. Rainbow trout and razorback suckers are raised in the Lake Mead Fish Hatchery by Nevada Department of Wildlife (NDOW). NDOW obtains its water supply for the fish hatchery from Lake Mead. This water comes from the Basic Management, Inc. (BMI) intake at reservoir elevation of 1,060 feet msl. Under recent conditions, the hatchery has experienced problems with water temperature and total dissolved solids in its water from the intake (Parke 2006). Water temperature taken at the intake is approximately 24°C, which is too warm for trout. NDOW has noticed that the increase in water temperatures start when Lake Mead's elevation is less than 100 feet above the BMI intake (elevation 1,160 feet msl and less). The 50th and 10th percentile monthly elevations are never above 1,160 feet msl so temperature problems are likely to persist for future hatchery operations. The 90th percentile elevations are identical for all alternatives and would alleviate the hatchery's temperature problems. The 50th percentile elevations are always above 1,060 feet msl, but the 10th percentile elevations for all alternatives fall below 1,060 feet msl in the future. Thus, the hatchery may have water supply problems at the 10th percentile elevation values.

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 Alternatives. The Basin States and Conservation Before Shortage Alternatives, and the Preferred Alternative, would be similar to the No Action Alternative. The Reservoir Storage Alternative is the most beneficial to the hatchery's water supply and the Water Supply Alternative would have the most adverse effects on water temperature. Effects on threadfin shad and striped bass are expected to be similar to the effects at Lake Powell, and substantial temperature-related impacts to the reservoir sport fishery are not anticipated to occur under any of the alternatives.

4.12.5 Recreation from Hoover Dam to SIB

Flow releases from Hoover Dam, Davis Dam, Parker Dam, and Imperial Dam will all be within historical operating range. Therefore, there would be minimal changes in exposure to boating navigation hazards caused by changes in river elevation; changes in exposure to boating navigation hazards caused by changes 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 decrease 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 are not expected to affect warm water sport fish.

4.12.6 Summary

4.12.6.1 Shoreline Facilities

For shoreline public use facilities at Lake Powell, there is a 16 percent chance that the launch ramp at Antelope Point marina would close or need to be modified under the No Action Alternative. Under the Preferred Alternative, the chance is 19 percent. There is a three to 10 percent probability that the Wahweap and lower Bullfrog launch ramps may close in 2026 under the No Action Alternative, the Basin States, Conservation Before Shortage, and Reservoir Storage Alternatives, and the Preferred Alternative, while under the Water Supply Alternative there is a 23 percent probability of this occurrence. Other marinas and launch ramps are similarly affected under the different alternatives.

There is a 43 percent probability under the No Action Alternative that in 2026 NPS would have to close or modify recreational facilities at the Rainbow Bridge National Monument. The probability of facility closures under the action alternatives would be 39 to 61 percent.

At Lake Mead, under all of the alternatives there is a 74 to 78 percent probability that the Pearce Bay launch ramp would be closed to boaters, except under the Reservoir Storage Alternative this probability is 66 percent. Similarly, there is a 21 to 30 percent probability of closure of the Echo Bay public launch ramp (in the north end of the reservoir) under all of the alternatives, except under the Reservoir Storage Alternative this probability is nine percent.

4.12.6.2 Safe Boating and Navigation

For safe boating at Lake Powell, probabilities range from 24 to 28 percent that NPS would have to prohibit boating around Castle Rock and Gregory Butte under the No Action Alternative and the Reservoir Storage Alternative. Under the Basin States Alternative there is a 36 percent probability and under the Conservation Before Shortage Alternative there is a 35 percent probability that boating prohibitions would need to be put in place. Under the Water Supply Alternative the probability of this occurrence is 52 percent. Under the Preferred Alternative there is a 32 percent probability that prohibitions would be put in place. For Lake Mead, all the alternatives except the Reservoir Storage Alternative in July 2026 provide a 72 to 76 percent probability that boaters may encounter navigational hazards upstream end of Lake Mead due to reservoir elevations being drawn down to below 1,170 feet msl. Under the Reservoir Storage Alternative there is a 69 percent probability of a similar recreational impact. Similar effects would occur in the Overton Arm of Lake Mead.

For whitewater boating through Grand Canyon, the Glen Canyon Dam ROD flows will be maintained. Even in a 7.0 maf Glen Canyon Dam release year, the minimum daily flow will remain at or above 5,000 cfs, a safe boating threshold.

4.12.6.3 Sport Fish Populations

Sport fish populations would not be adversely affected at Lake Powell under any of the alternatives. Although surface water temperatures may approach lethal levels in the upper 10 feet of the reservoir under any alternative, lethal levels for striped bass and threadfin shad are not expected to be exceeded by any alternative. Moreover, cooler temperatures below the lake surface would serve as a refuge for the fish. The situation for striped bass and threadfin shad in Lake Mead is similar to Lake Powell. Higher water temperatures could impair the Lake Mead Fish Hatchery, particularly under the Water Supply Alternative.

Under the No Action Alternative, 10^{th} percentile temperatures are suitable for growth, spawning, and incubation in the months presented in Table 4.12-2. Higher water temperatures under the Basin States, Conservation Before Shortage, and Water Supply alternatives, and the Preferred Alternative, could affect various life history stages of rainbow trout downstream of Glen Canyon Dam. Under the action alternatives, 10^{th} percentile modeling results indicate that there could be minor impacts to rainbow trout due to warmer temperatures. The Water Supply Alternative shows the most warming and potential to negatively impact trout. The Reservoir Storage Alternative shows the least warming and will often result in colder temperatures than the No Action Alternative. Conditions for trout under the Basin States, Conservation Before Shortage, and Water Supply alternatives, and the Preferred Alternative, will be similar to slightly worse than under the No Action Alternative.

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4.13 Transportation

This section describes the methods of analysis and potential effects on transportation, focusing on ferry services and river taxis.

4.13.1 Methodology

4.13.1.1 Effects on Lake Powell Ferry Service

The John Atlantic Burr Ferry becomes inoperable when Lake Powell elevation falls below 3,550 feet msl, requiring additional driving of approximately 130 miles between the Bullfrog and Halls Crossing marinas. Consequently, for each action alternative, the analysis evaluates the probability of the ferry becoming inoperable and compares that to the probability under the No Action Alternative. These comparisons were based on Lake Powell end-of-September elevations between 2008 through 2060 (Table 4.13-1, Figure 4.3-10, and Table 4.3-9).

4.13.1.2 Effects on Laughlin River Taxis and Tour Boats

Changes in releases from Davis Dam have the potential to impact the operations of river taxi services and tour boats in Laughlin, Nevada. The projected discharges or flows were compared to the flows required by the river taxis and the tour boats.

4.13.1.3 Effects on Lake Havasu Ferry Service

Changes in Lake Havasu elevations could affect the existing ferry service and recreational uses. Effects of changes in Lake Havasu elevations on recreational uses are discussed in the recreational impacts discussion (Section 4.12). The discussion presented below is limited to the potential effects on ferry service provided on Lake Havasu.

4.13.2 Lake Powell Ferry Service

Table 4.13-1 lists the range of probabilities of Lake Powell elevations being less than or equal to 3,550 feet msl for each alternative. An analysis for each alternative is provided below.

Table 4.13-1
Range of Probabilities (percent) of Lake Powell Elevations Less Than or Equal 3,550 feet msl

Alternative	2008 through 2026	2026 through 2060
No Action	0 to 5	4 to 7
Basin States	0 to 7	5 to 7
Conservation Before Shortage	0 to 7	5 to 7
Water Supply	0 to 17	8 to 17
Reservoir Storage	0 to 3	1 to 7
Preferred Alternative	0 to 7	5 to 7

4.13.2.1 No Action Alternative
The likelihood that Lake Powell elevations would fall below 3,550 feet msl under the No Action Alternative is not greater than seven percent for all years (zero to seven percent; Table 4.13-1, Figure 4.3-10, and Table 4.3-9). Consequently, the Lake Powell ferry service would be able to operate 93 percent or more of the time under the No Action Alternative.

4.13.2.2 Basin States Alternative
The Basin States Alternative would result in very similar or slightly higher probabilities (zero to seven percent) of Lake Powell elevations being less than 3,550 feet msl when compared to the No Action Alternative for the period 2008 through 2026 (Table 4.13-1, Figure 4.3-10, and Table 4.3-9). For the period 2026 through 2060, the Basin States Alternative would result in similar or slightly higher probabilities (five to seven percent) as compared to the No Action Alternative. The net effect under this alternative is minor.

4.13.2.3 Conservation Before Shortage Alternative
The Conservation Before Shortage Alternative would result in very similar or slightly higher probabilities (zero to seven percent) of Lake Powell elevations being less than 3,550 feet msl when compared to the No Action Alternative for the period 2008 through 2026 (Table 4.13-1, Figure 4.3-10, and Table 4.3-9). For the period 2026 through 2060, the Conservation Before Shortage Alternative would result in similar or slightly higher probabilities (five to seven percent) as compared to the No Action Alternative. The net effect under this alternative is minor.

4.13.2.4 Water Supply Alternative
The Water Supply Alternative would result in similar or higher probabilities (zero to 17 percent) of Lake Powell elevations being less than 3,550 feet msl when compared to the No Action Alternative for the period 2008 through 2026 (Table 4.13-1, Figure 4.3-10, and Table 4.3-9). For the period 2026 through 2060, the Water Supply Alternative would result in higher probabilities (eight to 17 percent) as compared to the No Action Alternative. The net effect under this alternative is moderately adverse.

4.13.2.5 Reservoir Storage Alternative
The Reservoir Storage Alternative would result in similar or slightly lower probabilities (zero to three percent) of Lake Powell elevations being less than 3,550 feet msl compared to the No Action Alternative for the period 2008 through 2026 (Table 4.13-1, Figure 4.3-10, and Table 4.3-9). For the period 2026 through 2060, the Reservoir Storage Alternative would result in similar or slightly lower probabilities (one to seven percent) as compared to the No Action Alternative. The net effect under this alternative is beneficial.

4.13.2.6 Preferred Alternative

The Preferred Alternative would result in similar or slightly higher probabilities (zero to seven percent) of Lake Powell elevations being less than 3,550 feet msl compared to the No Action Alternative for the period 2008 through 2026 (Table 4.13-1, Figure 4.3-10, and Table 4.3-9). For the period 2026 through 2060, the Preferred Alternative would result in similar or slightly higher probabilities (five to seven percent) as compared to the No Action Alternative. The net effect under the Preferred Alternative is minor.

4.13.3 Laughlin River Taxis and Tour Boats

The minimum future flow under the No Action Alternative and under the action alternatives will continue to be 2,300 cfs, the minimum flow needed to run one turbine of the Davis Powerplant at about one-half capacity. The duration of flows in the 2,300 to 4,600 cfs range would not be affected by the proposed federal action. However, the duration of flows in the 4,600 cfs to 9,200 cfs range may be affected by the proposed federal action. For example, due to changes in annual releases, the duration of hourly flows in the 4,600 to 9,200 cfs range may increase during some days under the Water Supply Alternative and decrease during some days under the Reservoir Storage Alternative. These changes have a minor effect on transportation. The duration of hourly flows in the 4,600 cfs to 9,200 cfs range under the Basin States and Conservation Before Shortage alternatives, and the Preferred Alternative are expected to be nearly the same as those under the No Action Alternative.

4.13.4 Lake Havasu Ferry Service

Lake Havasu will continue to be operated to meet monthly elevation targets; therefore, adoption of any of the alternatives would not affect the operation of the Lake Havasu ferry service.

4.13.5 Summary

For the Lake Powell ferry, the Basin States and Conservation Before Shortage alternatives, and the Preferred Alternative would have minor effects on ferry service; the Water Supply Alternative could result in potential moderate adverse effects; and the Reservoir Storage Alternative could have beneficial effects. The probability varies from year to year, but there is up to a 17 percent probability that the Lake Powell ferry may become inoperable under the Water Supply Alternative for some period of time. Conversely, the ferry would remain operable with the highest probabilities and greatest durations of time under the Reservoir Storage Alternative.

For the Colorado River ferry service downstream of Davis Dam, only under the Reservoir Storage Alternative are there any measurable effects and these potential effects would be minor. The other action alternatives show no difference from the No Action Alternative.

The Lake Havasu ferry service would be unaffected under all of the action alternatives.

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4.14 Socioeconomics

This section describes the potential impacts of the proposed federal action with respect to socioeconomics and describes the methods used to determine and analyze those impacts. Included in this analysis are the potential impacts to employment, income and tax revenue due to changes in agricultural production. Also included are the potential socioeconomic impacts to M&I and recreation uses. The study area and issues associated with these resources are described in Section 3.14. Additional details on the assessment of the socioeconomic effects is provided in Appendix H. Cumulative impacts related to socioeconomics use are discussed in Chapter 5.

4.14.1 Methodology

This section describes the methods used to estimate the effects on socioeconomics resulting from the proposed federal action. The assessment focused on estimating the socioeconomic effects that might occur as a result of potential changes in agricultural production, reservoir-related and river-related recreation, and the change in M&I water availability.

4.14.1.1 Agriculture

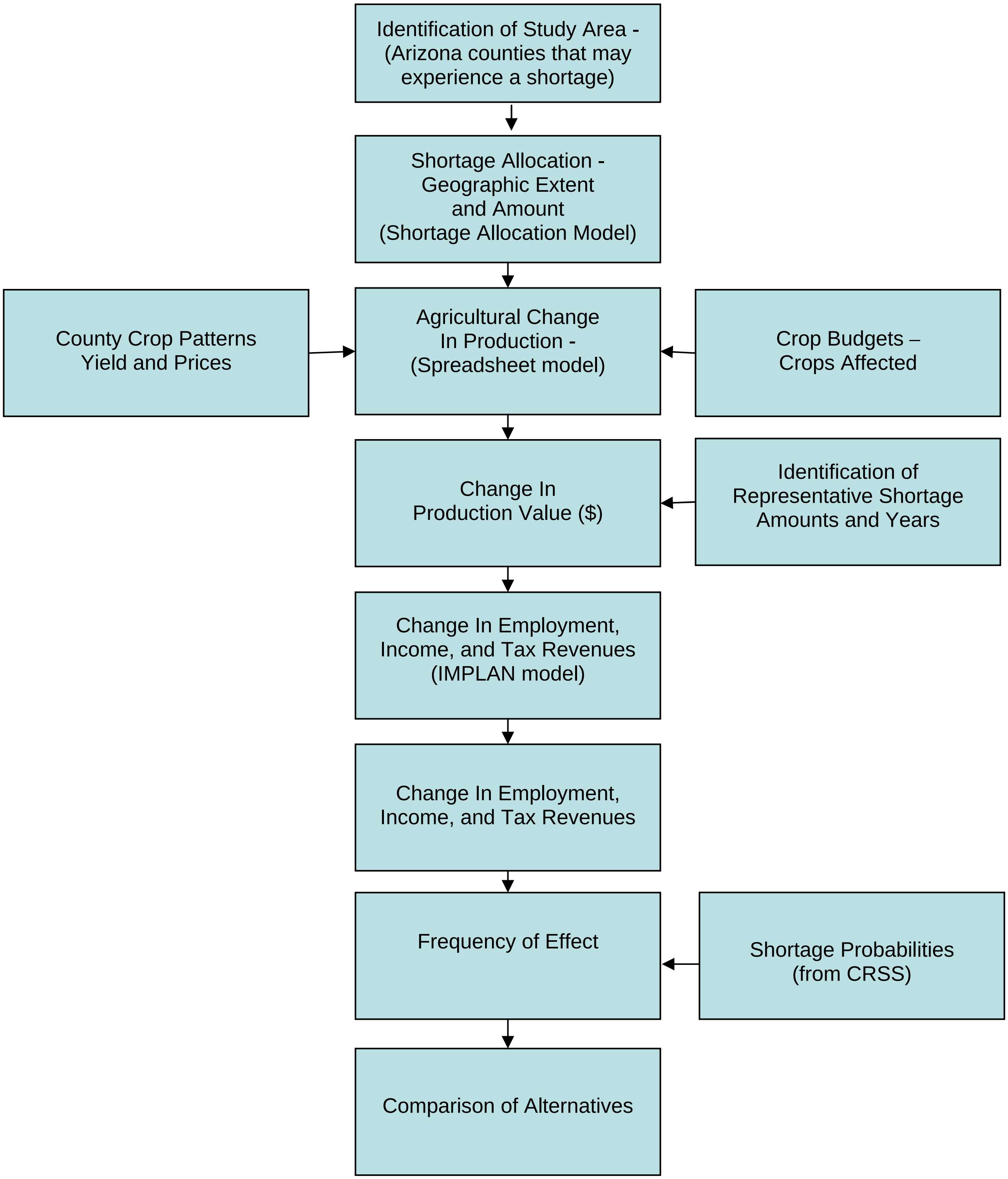
The potential socioeconomic effects due to changes in agricultural production were quantitatively assessed for Arizona agricultural districts and the corresponding counties that would likely experience shortages (i.e., within the CAP service area and the 4th priority agricultural use along the river). An assessment of potential socioeconomic effects due to changes in agricultural production in Nevada was not necessary since shortages of the magnitudes generated by the alternatives would only affect the M&I sector. An assessment of potential socioeconomic effects in California was also not necessary since shortages of the magnitudes generated by the alternatives would primarily affect the M&I sector. Shortages of significant magnitude that would affect agricultural users in California were observed to be very unlikely to occur, and if shortages of this nature occurred, the result would be limited to insignificant reductions in water use relative to California agricultural entitlements.

The quantitative assessment was conducted in three major steps:

- ♦ estimating changes in agricultural production as the result of reduced water deliveries;
- ♦ estimating the potential changes in employment, income, and tax revenue as a result of reduced water deliveries; and
- ♦ applying the shortage probabilities for a particular shortage amount and year to assess the likelihood that the potential changes would occur.

Figure 4.14-1 provides an overview of the steps followed in conducting the assessment of changes in agricultural production and resulting changes in employment, income, and tax revenues.

Figure 4.14-1
Steps in Analyzing Changes in Agricultural Production
and Resulting Changes in Employment, Income, and Tax Revenue



Estimating Changes in Agricultural Production Value:

Involuntary Shortages. The purpose of the impact assessment for agriculture is to estimate the change in agricultural production values as a result of the proposed federal action. Specifically, this section focuses on the incidence of these impacts on non-Indian and Indian agricultural production in Pinal, Maricopa, Pima, Mohave, La Paz, and Yuma counties for 2008, 2017, 2026, 2027, 2040, and 2060. The six counties were selected because the agricultural districts that may experience shortages are located within these counties. Impacts to agriculture in the six-county area were examined by observing modeled changes in industry output and acreage of fallowed lands for agriculture. The years 2008, 2017, and 2026, were selected because they represent the beginning, midpoint, and end of the interim period. The years 2027, 2040, and 2060 were selected because they represent the beginning, midpoint, and end of the remaining period of analysis.

The objectives of this study were to quantify potential:

- changes in agricultural production for various levels of shortage; and
- amounts of fallowed land for various levels of shortage.

Key to this impact analysis is the assumption that the most conservative way to estimate impacts is to assume that, if a shortage occurs, farmers would react by fallowing irrigated lands. The decision to fallow lands would rest on the ability of the farmer to cover the variable costs of production for crops grown in the study area. These assumptions are discussed in more detail later in this section.

While fallowing of lands may occur during shortages, there are other sources of water that may be used by farmers in order to offset shortages. For example, a farmer may have a groundwater well available and may be able to mitigate shortages in surface water supply by pumping additional groundwater. Other farmers may be able to take delivery of groundwater that is recovered from a groundwater bank. 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, for the purposes of this analysis, the projected change in agricultural production was based on the conservative assumption that other sources of water would not be available.

The potentially affected crops considered included cotton, wheat, alfalfa, vegetables and melons, and trees and vines. The primary focus is on cotton, wheat, and alfalfa because these crops have lower earnings per acre-foot of water than fruit, vegetable, and nut crops and, therefore, are more vulnerable to changes in water costs and shortages. Farm budgets were developed for cotton, wheat, and alfalfa to determine the maximum water cost a farmer can pay and still produce a particular crop. These budgets represent a generalization of the variable production costs for a particular crop exclusive of water costs. When the cost of water exceeds the maximum water cost a farmer can pay or if water is not available, a crop is taken out of production and the land is fallowed for the year in which a shortage occurs. The data from all of the model runs for the action alternatives were compared to those of the No Action Alternative.

General Assumptions and Data Sources:

Crop Patterns, Yields, and Prices. Crop patterns, yield per acre, and prices were assumed to remain constant for non-Indian and Indian agricultural output for all alternatives during the study period. Crop patterns for the CAP and other irrigation districts in this study are based on historical crop patterns that were reported by irrigation districts to Reclamation for the years 1999 through 2004. These data were averaged and aggregated at the county level for the impact analysis. Cropping patterns for Indian agriculture come from a variety of sources and may be incomplete. Accordingly, it was assumed that cropping patterns on Indian lands were similar to that of nearby irrigation districts. Appendix H includes information on cropping patterns for CAP and other irrigation districts.

Yield data was based on five-year average county-level yields for the period 2000 through 2005. Prices are based on five-year average statewide prices for Arizona for the period 2000 to 2005. The yield and price data are published by the USDA’s National Agricultural Statistics Service (NASS) for Arizona. Information on county-level yield and price data is provided in Appendix H.

Water Costs. The cost of water used in the analysis of agricultural impacts is a blended cost that reflects the price of CAWCD excess water pools, groundwater pumping, and other water. The price of CAWCD excess water was obtained directly from the CAWCD. Cost estimates for groundwater pumping and other water were obtained from various irrigation districts. These data were aggregated to a county-level basis for use in the agricultural impacts analysis. The blended cost of water data for each county is included in Appendix H.

Crop Budgeting and Impacts upon Crop Selection due to Water Cost and Water Shortages. Crop budgets were developed to determine the crop types that would be affected as a result of water shortages. A detailed description of how the crop budgets were developed is included in Appendix H.

Assessment of Changes in Agricultural Production. It is assumed that the agricultural impacts for involuntary shortages are the same for various levels of shortage for each alternative. As an example, a 600,000 af shortage occurring under the Reservoir Storage Alternative would result in the same change in agricultural production as a 600,000 af shortage occurring under the Basin States Alternative. Shortages may occur more or less frequently under various alternatives, but the change in agricultural production during a particular volume of shortage was assumed to be the same across the alternatives. This is due to the modeling assumptions made with regard to how shortages might be distributed to various water users (Section 4.2, Appendix A, and Appendix G). These assumptions are the same across all alternatives. Changes in agricultural production and resulting changes in production value due to voluntary shortages would likely be different than the changes due to involuntary shortages, discussed in additional detail below.

Output from Reclamation's Shortage Allocation Model (Section 4.2 and Appendix G) was used as input for assessing changes in agricultural production during the involuntary fallowing of agricultural lands. The various levels of shortage were input into the model and the amount of shortage that would be allocated to various agricultural users was generated. These results were aggregated on a county-level basis for use in the agricultural impacts analysis.

Impacts for both non-Indian and Indian agriculture were analyzed independently. For both analyses, the shortage allocated to non-Indian and Indian water users in each county for various levels of overall shortage were input into a spreadsheet model developed by Reclamation that estimates changes in agricultural production and production value. Model input includes output from the partial crop budgets, the amount of available surface water in each county, county-wide shortage amounts from the water allocation model, the amount of water applied per acre for each crop, and county-wide water distribution patterns with respect to cotton, wheat, and alfalfa production. Based on the amount of shortage realized in each county, the model estimates the amount of land that would be fallowed using the relative profitability of each crop. The model assumes that the least profitable crops are fallowed first. Once all of the irrigated land associated with the least profitable crop is fallowed, the model assumes that fallowing of the next-least profitable crop would commence. The irrigated acreage associated with fallowing is estimated based on the amount of water allocated to various crops and the crop water use per acre associated with those crops. The resulting direct economic impacts are calculated by multiplying the number of acres fallowed for various crops by the gross output for those crops.

The federal government has reserved a volume of CAP water in the range of 47,000 to 67,000 af for future water settlements. At some time, this water may be allocated to tribes in Arizona for agricultural or M&I use. Once allocated, this water would potentially be vulnerable to shortages. However, it is not known where or when this water may be allocated. Because of this uncertainty, the reserved federal government water has not been included in the analysis.

Shortages. The partial farm budgets used in the analysis of involuntary shortages are a potential means to estimate the minimum amount of compensation a farmer would accept to fallow agricultural ground. However, compensation rates included in recently established fallowing programs do not reflect these minimum amounts. It appears that market forces have contributed significantly to the compensation rates paid in fallowing programs for conserved water. As a result, available data from several fallowing programs were used to estimate a range of costs for conserved water and to estimate potential amounts of land that would be fallowed under various levels of shortage.

Data from several sources suggest that fallowing agricultural lands would result in a reduction in the consumptive use of water ranging between 4.2 and 6.9 af per acre (Colby et al. 2006). The amount of acreage that would be fallowed would be dependent on the crops grown and the consumptive use of those crops. However, again, it is difficult to project which irrigators or districts would fallow their land and what crops would not be grown. In lieu of attempting to project the crops that would not be grown, for the purposes of this study, it was assumed that the amount of fallowed land per acre-foot of conserved water would be similar to the range shown above. It was assumed that all of the potentially conserved water results from agricultural water conservation.

Voluntary shortages may result in a beneficial effect on farmers rather than a detriment. The minimum amount of water a farmer would likely accept would be at a break-even price. However, given the demand for water conservation under voluntary shortages, a farmer would be less likely to accept a minimum payment and would be more likely to attempt to maximize economic gain.

Implementation of voluntary shortages is the focus of the Conservation Before Shortage Alternative. The water conservation (voluntary shortage) prior to involuntary shortage included in this alternative assumes that farmers would be compensated to initiate voluntary water conservation measures. These conservation measures could be implemented in a variety of ways such as on-farm efficiency improvements, canal lining, etc. It is, however, difficult to project what actions individual farmers or irrigation districts might take in the future to conserve water. Land fallowing programs have frequently been used as a means to voluntarily conserve water and fallowing would likely result in the most significant impacts with regard to land use. For the purposes of this study, it is assumed that land fallowing would be the means of conserving water for the Conservation Before Shortage Alternative.

Estimating Changes in Employment, Income, and Tax Revenue. The socioeconomic effects of changes in agricultural production in Arizona were analyzed using the IMPLAN 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, using the input-output multipliers, total regional economic activity based on a change in expenditures.

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. The resulting socioeconomic effects were quantified as changes in employment, income, and tax revenue.

The qualitative assessment for changes in agricultural production and resulting changes in employment, income, and tax revenues was based on the probability of shortages occurring in the agricultural sector in California and Nevada.

4.14.1.2 Municipal and Industrial Water Uses

The potential socioeconomic consequences of shortages occurring in the M&I sector were qualitatively assessed for Arizona, California, and Nevada. The effects were qualitatively assessed because it was not known to what degree a specific economic sector considered an M&I use would be affected. The analysis was based on the shortage amounts and shortage allocations reported in Section 4.4.

The analysis first examined the probability of a range of water shortages occurring in different years. The shortages analyzed included 400,000 af, 500,000 af, 600,000 af, 800,000 af, 1 maf, 1.2 maf, 1.8 maf, and 2.5 maf. Consistent with the assessment of the effects to agriculture, the M&I analysis examined years 2008, 2017, 2026, 2027, 2040, and 2060 for each of the shortage amounts.

The analysis focused on those years and shortage levels having the highest probability of occurrence and where the probability was substantially different under the action alterative compared to the No Action Alternative. The analysis then examined whether a particular shortage event would affect the M&I sector as compared to the No Action Alternative. For example, a shortage in Arizona would affect the agricultural sector first. In contrast, a shortage in Nevada would affect M&I, primarily because Nevada has a small agricultural sector that is dependant on 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 to 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.

4.14.1.3 Recreation

The recreation-related socioeconomic effects resulting from changes in Lake Powell and Lake Mead elevations and flows in the Colorado River downstream of Lake Powell and Lake Mead were qualitatively assessed. The conclusions regarding the extent of changes in reservoir elevations and river flows reported in Section 4.3 and recreation opportunities reported in Section 4.12 were used to help determine the magnitude of socioeconomic effects.

Lake Powell and Lake Mead. The assessment of changes in recreation-related economic activity was based on changes in Lake Powell and Lake Mead elevations. Particular months representative of the primary recreational season were selected for each lake to analyze the potential elevation changes (September for Lake Powell; July for Lake Mead).

Figure 4.14-2 depicts the end-of-September Lake Powell elevations and Figure 4.14-3 depicts the end-of-July Lake Mead elevations used in this analysis. The years considered in the assessment are 2008, 2016, 2026, and 2060. For each year, lake elevations for each alternative were compared to the No Action Alternative. This comparison was conducted for the 90th, 50th, and 10th percentiles as shown in Figures 4.14-2 and 4.14-3.

Colorado River Downstream of Lake Powell and Lake Mead. The assessment of socioeconomic effects as a result of changes in recreation-related economic activity was based on the results of the recreation assessment. The results of this assessment are provided in Section 4.12.

Figure 4.14-2
Lake Powell End-of-September Elevations
Comparison of Action Alternatives to No Action Alternative
90th, 50th, and 10th Percentile Values

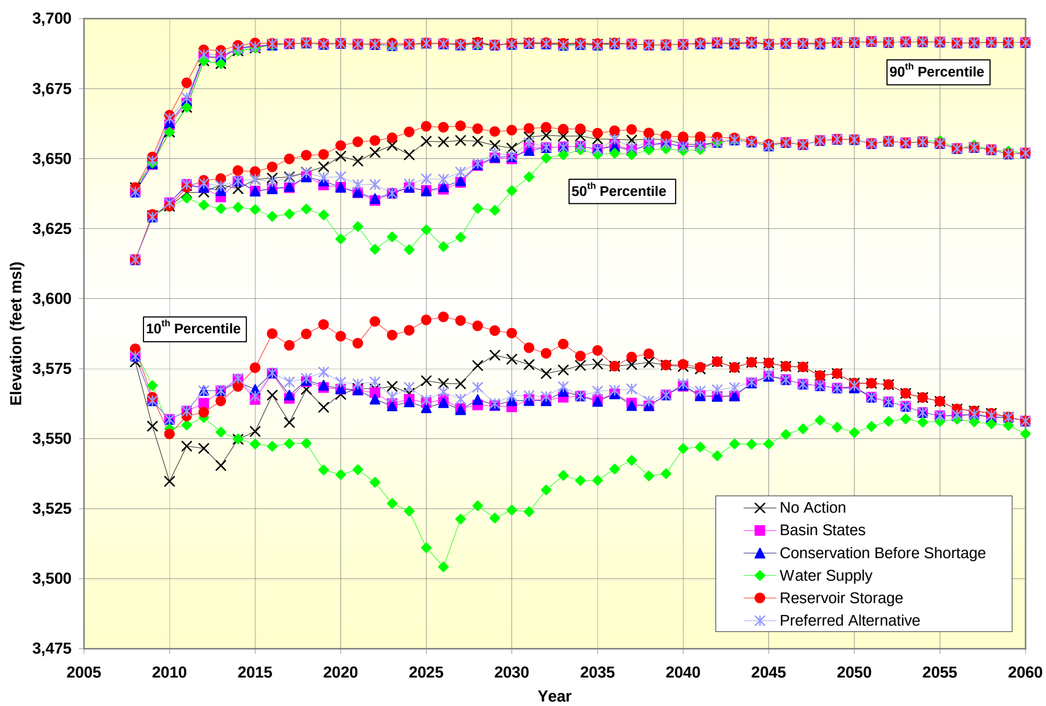
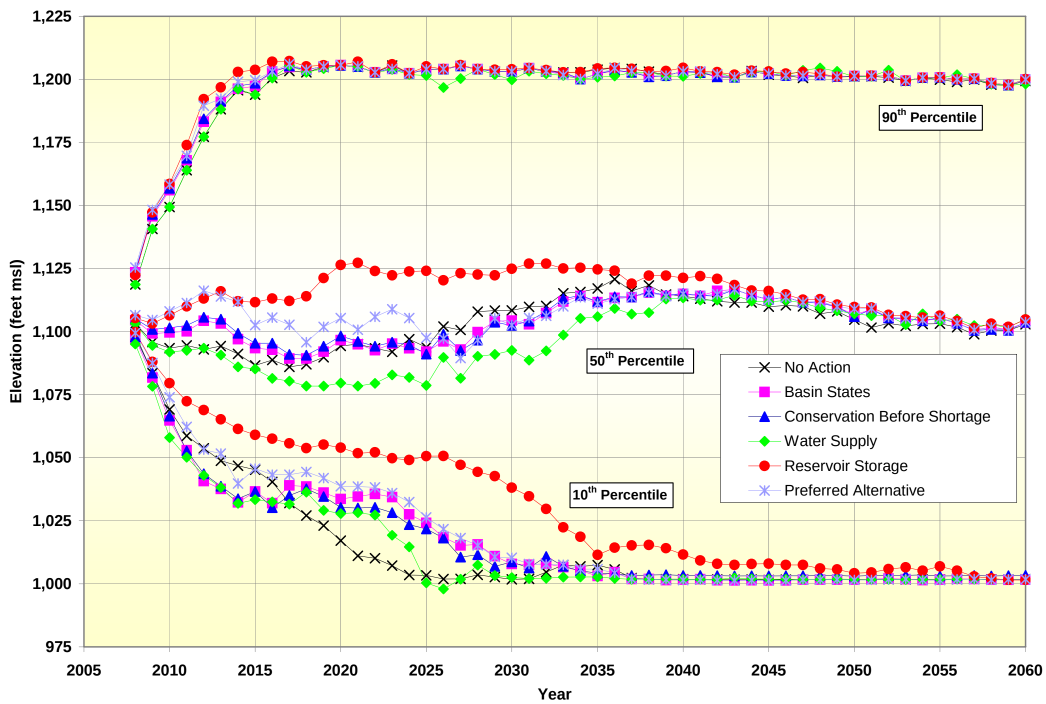


Figure 4.14-3
Lake Mead End-of-July Elevations
Comparison of Action Alternatives to No Action Alternative
90th, 50th, and 10th Percentile Values



4.14.2 Potential Impacts to Agriculture

This section provides the assessment of potential effects on agricultural production and resulting changes in employment, income, and taxes. The potential socioeconomic effects due to changes in agricultural production were only assessed for Arizona agricultural districts and the corresponding counties that would likely experience shortages (i.e., within the CAP service area and the 4th priority agricultural use along the Colorado River). Table 4.14-1 provides estimates of involuntary fallowed agricultural land for each shortage amount. Table 4.14-2 provides estimates of changes in agricultural production value for each shortage amount. The change in production value was used as input to IMPLAN to estimate changes in employment, income, and tax revenue.

Table 4.14-1 provides the total estimated fallowed acreage for each shortage amount for 2008, 2017, 2026, 2027, 2040, and 2060. No change in production would occur in 2008 because no shortages are projected to occur in that year. In general, for each shortage amount, the amount of fallowed non-Indian agricultural land decreases between 2017 and 2060 reflecting the trend of fewer acres of agricultural land being in production in the future. No permanent change in land uses would occur under any of the alternatives because shortages would be of a temporary nature and agricultural lands would likely not be permanently removed from production.

The changes in agricultural production values are shown in Table 4.14-2. These changes are a direct result of the amount of land fallowed for each shortage amount. Similar to the acreages of fallowed land, the changes in production value is expected to decrease as a result of less land being fallowed in the future for non-Indian agriculture.

Table 4.14-1
Estimate of Involuntarily Fallowed Acres in Arizona under Various Levels of Shortage for Various Years

Shortage Amount (af)	Non-Indian Agriculture					
	2008	2017	2026	2027	2040	2060
400,000	-	75,923	32,849	-	-	-
500,000	-	78,395	34,450	119,966	6,582	6,365
600,000	-	80,071	35,445	21,061	7,683	7,466
800,000	-	82,253	37,603	23,251	9,884	9,668
1,000,000	-	84,383	39,767	25,385	12,024	11,810
1,200,000	-	86,073	41,453	27,070	13,702	13,485
1,800,000	-	-	-	37,521	24,750	24,534
2,500,000	-	-	-	92,489	-	-
Shortage Amount (af)	Indian Agriculture					
	2008	2017	2026	2027	2040	2060
400,000	-	1,391	34,515	-	-	-
500,000	-	6,878	48,226	54,936	52,704	50,009
600,000	-	24,171	54,503	61,276	59,442	56,709
800,000	-	42,171	67,026	72,594	69,876	67,373
1,000,000	-	54,517	76,758	83,674	81,641	78,443
1,200,000	-	65,285	88,655	95,899	93,822	90,615
1,800,000	-	-	-	127,254	124,458	121,246
2,500,000	-	-	-	129,826	-	-
Shortage Amount (af)	Total Agriculture					
	2008	2017	2026	2027	2040	2060
400,000	-	77,314	67,364	-	-	-
500,000	-	85,273	82,577	74,902	59,286	56,374
600,000	-	104,241	89,948	82,337	67,124	64,175
800,000	-	124,424	104,630	95,845	79,760	77,040
1,000,000	-	138,900	116,525	109,059	93,665	90,254
1,200,000	-	151,358	130,108	122,969	107,524	104,100
1,800,000	-	-	-	164,774	149,208	145,780
2,500,000	-	-	-	222,315	-	-

Note: a dash indicates that a shortage of the given magnitude did not occur in that particular year and therefore there is no change in production value.

Table 4.14-2
Estimated Reduction in Agricultural Production Value Resulting from Involuntary Land Fallowing in Arizona under Various Levels of Shortage for Various Years

Shortage Amount (af)	Non-Indian Agriculture					
	2008	2017	2026	2027	2040	2060
400,000	-	$52,036,229	$13,822,198	-	-	-
500,000	-	$54,123,481	$14,619,316	$8,736,471	$3,262,717	$3,173,387
600,000	-	$55,368,017	$15,246,164	$9,363,844	$3,893,755	$3,804,424
800,000	-	$56,618,464	$16,488,324	$10,618,453	$5,155,026	$5,065,695
1,000,000	-	$57,927,001	$17,817,032	$11,935,945	$6,485,636	$6,397,060
1,200,000	-	$59,415,581	$19,309,607	$13,428,638	$7,985,489	$7,896,159
1,800,000	-	-	-	$19,747,836	$14,530,354	$14,441,155
2,500,000	-	-	-	$43,070,889	-	-
Shortage Amount (af)	Indian Agriculture					
	2008	2017	2026	2027	2040	2060
400,000	-	$564,460	$19,041,437	-	-	-
500,000	-	$2,804,264	$25,723,590	$30,509,432	$27,414,204	$25,220,110
600,000	-	$9,896,242	$29,191,532	$33,983,138	$31,040,001	$28,806,579
800,000	-	$17,766,536	$36,693,514	$41,541,445	$38,520,958	$36,089,626
1,000,000	-	$25,899,839	$45,587,059	$52,706,860	$50,613,664	$47,274,619
1,200,000	-	$34,755,657	$57,905,625	$65,467,934	$63,331,456	$59,982,397
1,800,000	-	-	-	$98,266,029	$95,374,120	$92,019,841
2,500,000	-	-	-	$100,988,860	-	-
Shortage Amount (af)	Total Agriculture					
	2008	2017	2026	2027	2040	2060
400,000	-	$52,600,689	$32,863,635	-	-	-
500,000	-	$56,927,744	$40,342,906	$39,245,903	$30,676,921	$28,393,497
600,000	-	$65,264,259	$44,437,696	$43,346,982	$34,933,755	$32,611,003
800,000	-	$74,385,000	$53,181,838	$52,159,899	$43,675,984	$41,155,322
1,000,000	-	$83,826,840	$63,404,091	$64,642,805	$57,099,300	$53,671,680
1,200,000	-	$94,171,238	$77,215,231	$78,896,572	$71,316,945	$67,878,556
1,800,000	-	-	-	$118,013,865	$109,904,474	$106,460,995
2,500,000	-	-	-	$144,059,749	-	-

Note: a dash indicates that a shortage of the given magnitude did not occur in that particular year and therefore there is no change in production value.

4.14.2.1 Changes in Agricultural Production and Resulting Changes in Employment and Income in Arizona

This section describes the potential changes in employment and income for each alternative as a result of changes in agricultural production. The discussion is a summary of the impact analysis conducted for the Arizona counties that may experience a shortage resulting in changes in agricultural production. The results of this county-level assessment of changes in employment and income for each shortage amount, year, and county are provided in Appendix H. The counties analyzed are Maricopa, Pinal, Pima, Mohave, La Paz, and Yuma. A summary comparison of the effects on employment and income among the alternatives is provided at the end of this subsection.

Table 4.14-3 presents a comparison of the shortage amounts with the estimated changes in employment and income and lists the probabilities of occurrence for each alternative, based on Tables 4.4-5 through 4.4-9. Shortages generated by the alternatives that were not exactly equal to the amounts shown in Table 4.14-3 were counted at the next highest value for the probabilities listed in Table 4.14-3.

Table 4.14-3
Estimated Reduction in Employment as a Result of Shortages to Agricultural Lands for the Action Alternatives and the No Action Alternative
by Selected Years and Shortage Amounts

Shortage Amount (af)	2017							
	Shortage Probabilities for Each Alternative (percent)						Jobs	Income ($ million)
	NA	BS	CBS	WS	RS	PA		
400,000	-	-	-	2	-	-	(577)	(22.6)
500,000	45	15	-	-	-	16	(627)	(23.8)
600,000	-	13	-	-	-	8	(776)	(28.2)
800,000	-	3	-	-	18	3	(860)	(30.8)
1,000,000		-	1	-	16	-	(937)	(30.4)
1,200,000	1	-	-	-	2	-	(1,161)	(43.1)
1,800,000	-	-	-	-	-	-	-	-
2,500,000	-	-	-	-	-	-	-	-
Shortage Amount (af)	**2026**							
	Shortage Probabilities for Each Alternative (percent)						Jobs	Income ($ million)
	NA	BS	CBS	WS	RS	PA		
400,000	-	-	-	12	-	-	(425)	(13.5)
500,000	34	15	1	-	-	24	(561)	(18.0)
600,000	-	13	-	-		11	(600)	(18.8)
800,000	7	7	3	-	18	6	(683)	(21.6)
1,000,000	6	-	2	-	14	-	(770)	(25.0)
1,200,000	1	-	-	-	5	-	(1,105)	(39.7)
1,800,000	-	-	-	-	-	-	-	-
2,500,000	-	-	-	-	-	-	-	-

Table 4.14-3
Estimated Reduction in Employment as a Result of Shortages to Agricultural Lands for the Action Alternatives and the No Action Alternative by Selected Years and Shortage Amounts

Shortage Amount (af)	2027							
	Shortage Probabilities for Each Alternative (percent)						Jobs	Income ($ million)
	NA	BS	CBS	WS	RS	PA		
400,000	-	-	-	-	-	-	-	-
500,000	38	48	44	37	38	50	(522)	(17.3)
600,000	1		-	-	-	-	(557)	(17.5)
800,000	3	2	2	1	-	-	(657)	(21.3)
1,000,000	2	-	2	-	-	1	(741)	(25.0)
1,200,000	1	-	1	1	-	-	(1,012)	(36.9)
1,800,000	3	-	-	3	-	-	(1,271)	(46.4)
2,500,000	-	1	-	4	-	-	(1,693)	(56.5)
Shortage Amount (af)	2040							
	Shortage Probabilities for Each Alternative (percent)						Jobs	Income ($ million)
	NA	BS	CBS	WS	RS	PA		
400,000	-	-	-	-	-	-	-	-
500,000	37	35	33	34	44	36	(419)	(13.4)
600,000	2	-	2	1	-	-	(460)	(14.6)
800,000	4	5	3	5	-	4	(534)	(17.7)
1,000,000	2	2	2	3	2	1	(649)	(22.3)
1,200,000	2	3	7	1	1	4	(777)	(27.5)
1,800,000	3	3	2	2	2	3	(1,181)	(43.5)
2,500,000	-	-	-	-	-	-	-	-
Shortage Amount (af)	2060							
	Shortage Probabilities for Each Alternative (percent)						Jobs	Income ($ million)
	NA	BS	CBS	WS	RS	PA		
400,000	-	-	-	-	-	-	-	-
500,000	54	54	50	51	53	52	(397)	(12.3)
600,000	1	1	3	2	1	1	(434)	(13.5)
800,000	4	6	6	4	6	6	(510)	(16.5)
1,000,000	3	1	1	2	1	1	(602)	(20.6)
1,200,000	3	3	4	3	4	3	(741)	(26.0)
1,800,000	3	3	3	3	3	3	(1,149)	(42.0)
2,500,000	-	-	-	-	-	-	-	-

Note:
NA = No Action Alternative
WS = Water Supply Alternative
CBS = Conservation Before Shortage Alternative
BS = Basin States Alternative
RS = Reservoir Storage Alternative
PA = Preferred Alternative
- = No shortage occurring

No Action Alternative. Potential decreases in employment attributable to a shortage occurring under the No Action Alternative for the period 2008 through 2026 would range from a low of 561 jobs during a 500,000 af shortage in 2026 to a high of 1,161 jobs during a 1.2 maf shortage in 2017. Resulting losses in personal income range from a low of approximately $18.0 million to a high of approximately $43.1 million (Table 4.14-3).

For the period 2008 through 2026, a shortage of approximately 500,000 af would have the greatest probability of occurring, estimated at 34 percent in 2026 and 45 percent in 2017. This shortage amount would result in an estimated loss of up to 627 jobs and resulting reduction in personal income of approximately $23.8 million (Table 4.14-3). Even if considered to be permanent, these potential changes in jobs and personal income are not considered substantial because the changes represent less than one percent of total employment and personal income generated within the six-county study area in Arizona.

Potential decreases in employment attributable to a shortage occurring under the No Action Alternative for the period 2027 through 2060 would range from a low of 397 jobs during a 500,000 af shortage in 2060 to high of 1,271 jobs during a 1.8 maf shortage in 2027. Resulting losses in personal income over the same period would range from a low of approximately $12.3 million to a high of approximately $46.4 million (Table 4.14-3).

For the period 2027 through 2060, a shortage of approximately 500,000 af would have the greatest probability of occurring, ranging from 37 percent in 2040 to 54 percent in 2060. In 2060, a 500,000 af shortage would result in an estimated loss of 397 jobs and reduction in personal income of approximately $12.3 million (Table 4.14-3). Even if considered to be permanent, these potential changes in jobs and personal income are not considered substantial because the changes represent less than one percent of total employment and personal income within the six-county study area in Arizona.

Basin States Alternative. Potential decreases in employment attributable to a shortage occurring under the Basin States Alternative for the period 2008 through 2026 would range from a low of 561 jobs during a 500,000 af shortage in 2026 to a high of 860 jobs during an 800,000 af shortage in 2017 resulting in a loss in personal income ranging from approximately $18 million to $30.8 million (Table 4.14-3).

For the period 2008 through 2026, a shortage of 500,000 af would have the greatest probability of occurring at 15 percent in 2017 and 2026 with corresponding job losses of 561 in 2026 and 627 in 2017. Reductions in personal income would range form $18 million in 2026 to $23.8 million in 2017. Even if considered to be permanent, these potential changes in jobs and personal income are not considered substantial because the changes represent less than one percent of total employment and personal income within the six-county study area in Arizona. Potential decreases in employment attributable to a shortage occurring under the Basin States Alternative between 2027 and 2060 would range from a low of 397 jobs during a 500,000 af shortage in 2060 to a high of 1,693 jobs during a 2.5 maf shortage in 2027. Resulting losses in personal income would range from a low of approximately $12.3 million to a high of approximately $56.5 million (Table 4.14-3).

For the period 2027 through 2060, a shortage of 500,000 af would have the greatest probability of occurring, ranging from 35 to 54 percent. Corresponding losses in jobs would range from 397 in 2060 to 522 in 2027. Losses in personal income would range from $12.3 million to $17.3 million. (Table 4.14-3). Even if considered to be permanent, these changes in jobs and personal income are not considered substantial because the changes represent less than one percent of total employment and personal income within the six-county study area in Arizona.

Conservation Before Shortage Alternative. The results of the analysis reported in this discussion may underestimate the socioeconomic effects of particular shortages occurring under the Conservation Before Shortage Alternative. This analysis assumes that the voluntary conservation targets (400 kaf, 500 kaf, and 600 kaf at Lake Mead elevations 1,075 feet msl, 1,050 feet msl, and 1,025 feet msl, respectively) would be met, assuming that farmers would participate voluntarily in the program and that losses resulting from voluntary shortages would be offset by payments made to farmers to forgo raising crops. With these assumptions, only the potential impacts of involuntary shortages were analyzed in this section.

Potential decreases in employment attributable to an involuntary shortage occurring under the Conservation Before Shortage Alternative for the period 2008 through 2026 would range from a low of 561 jobs during a 500,000 af shortage in 2026 to a high of 937 jobs during a 1 maf shortage in 2017. Estimated losses in personal income would range from a low of approximately $18 million to a high of approximately $25 million (Table 4.14-3).

Shortages have a much greater probability of occurring under the No Action Alternative than under the Conservation Before Shortage Alternative. This suggests for the period 2008 through 2026 the probability of adverse socioeconomic effects occurring under the Conservation Before Shortage Alternative would be much less when compared to the No Action Alternative.

Potential decreases in employment attributable to a shortage occurring under the Conservation Before Shortage Alternative for the period 2027 through 2060 would range from a low of 397 jobs during a 500,000 af shortage in 2060 to a high of 1,181 jobs during a 1.8 maf shortage in 2040. Similarly, estimated losses in personal income over the same period would range from a low of approximately $12.3 million to a high of approximately $43.5 million (Table 4.14-3).

For the period 2027 through 2060, a shortage of 500,000 af would have the greatest probability of occurring, ranging from 33 percent to 50 percent. Estimated losses in jobs would range from 387 in 2060 to 522 in 2017. Corresponding losses in personal income would range from $12.3 million to $17.3 million (Table 4.14-3). Even if considered permanent, these job losses and reductions in personal income are not considered substantial because the changes represent less than one percent of total employment and personal income within the six-county study area in Arizona.

When compared to the No Action Alternative, the probabilities of shortages in 2027 under the Conservation Before Shortage Alternative are higher for shortages of 500,000 af and similar for greater shortages. However, in 2060 shortages of 500,000 af have a slightly lower probability of occurring under the Conservation Before Shortage Alternative and similar probabilities for higher shortage levels.

Water Supply Alternative. For the period 2008 through 2026, potential decreases in employment attributable to a shortage under the Water Supply Alternative would occur only during a 400,000 af shortage in 2017 and 2026. This would result in an estimated loss of 425 jobs in 2026 and 577 jobs in 2017. Losses in personal income would range from $13.5 million and $22.6 million (Table 4.14-3). This lack of shortages is a result of this alternative's strategy to provide full water deliveries until no water remains in Lake Mead, a reservoir draw down situation which has a low probability of occurring during the interim period.

Potential decreases in employment attributable to a shortage occurring under the Water Supply Alternative for the period 2027 through 2060 would range from a low of 397 jobs during a 500,000 af shortage in 2060 to a high of 1,693 jobs during a 2.5 maf shortage in 2060. Resulting losses in personal income over the same period would range from a low of approximately $12.3 million to a high of approximately $56.5 million (Table 4.14-3).

For the period 2040 through 2060, the probability of shortages under the Water Supply Alternative are very similar to those of the other alternatives, and shortages of 500,000 af would have the greatest probability of occurring, ranging from 37 percent to 51 percent. A 500,000 af shortage would result in an estimated loss of up to 527 jobs and reduction in personal income of up to $17.3 million. Even if considered to be permanent, these changes in jobs and personal income are not considered substantial because the changes represent less than one percent of total employment and personal income within the six-county study area in Arizona.

Reservoir Storage Alternative. Potential decreases in employment attributable to a shortage occurring under the Reservoir Storage Alternative for the period 2008 through 2026 would range from a low of 683 jobs during an 800,000 af shortage in 2026 to a high of 1,161 jobs during a 1.2 maf shortage in 2017. Resulting losses in personal income over the same period would range from a low of approximately $21.6 million to a high of approximately $43.1 million (Table 4.14-3).

For the period 2008 through 2026, a shortage of 800,000 af would have the greatest probability of occurring at 18 percent. Job losses during an 800,000 af shortage would range from 600 in 2026 to 860 in 2017 (Table 4.14-3). Losses in personal income would range from $18.8 million to $30.8 million. Even if considered to be permanent, these changes in jobs and personal income are not considered substantial because the changes represent less than one percent of total employment and personal income within the six-county study area in Arizona.

Shortages of 400,000 to 600,00 af have a much greater potential of occurring under the No Action Alternative whereas shortages of 800,000 af to 1.2 maf have a greater probability of occurring under the Reservoir Storage Alternative. This suggests that for the period 2008 through 2026 the probability of adverse socioeconomic effects occurring under the Reservoir Storage Alternative may be slightly less than under the No Action Alternative, but when shortages of greater than 800,000 af do occur, they are greater in magnitude with increased socioeconomic effects.

Potential decreases in employment attributable to a shortage occurring under the Reservoir Storage Alternative for the period 2027 through 2060 would range from a low of 397 jobs during a 500,000 af shortage in 2060 to a high of 1,181 jobs during a 1.8 maf shortage in 2040 (Table 4.14-3). Losses in personal income would range from a low of approximately $12.3 million to a high of approximately $43,5 million (Table 4.14-3).

For the period 2027 through 2060, a shortage of 500,000 af would have the greatest probability of occurring, ranging from 38 percent to 53 percent. Job losses during a 500,000 af shortage would range from 397 jobs in 2060 to 552 jobs in 2027. Losses in personal income would range from $12.3 million to $17.3 million (Table 4.14-3). Even if considered to be permanent, these changes in jobs and personal income are not considered substantial because the changes represent less than one percent of total employment and personal income within the six-county study area and Arizona.

The probabilities of shortages occurring under the Reservoir Storage Alternative during a 500,000 af shortage would be similar to the probabilities under the No Action Alternative.

Preferred Alternative. Potential decreases in employment attributable to a shortage occurring under the Preferred Alternative for the period 2008 through 2026 would range from a low of 561 jobs during a 500,000 af shortage in 2026 to a high of 860 jobs during an 800,000 af shortage in 2017. Resulting losses in personal income over the same period would range from a low of approximately $18 million to a high of approximately $30.8 million (Table 4.14-3).

For the period 2008 through 2026, a shortage of 500,000 af would have the greatest probability of occurring at 16 percent in 2017 and 24 percent in 2026. Job losses during an 500,000 af shortage would range from 561 in 2017 to 627 in 2017 (Table 4.14-3). Corresponding losses in personal income would range from $18 million to $23.8 million. Even if considered to be permanent, these changes in jobs and personal income are not considered substantial because the changes represent less than one percent of total employment and personal income within the six-county study area in Arizona.

Shortages of 500,000 af have a lower probability of occurring under the Preferred Alternative compared to the No Action Alternative whereas shortages of 600,000 and 800,000 af have a greater probability of occurring under the Preferred Alternative. This suggests that for the period 2008 through 2026 the probability of adverse socioeconomic effects occurring under the Preferred Alternative may be slightly lower during a 500,000 af shortage but greater for shortages between 600,000 and 800,000 af.

Potential decreases in employment attributable to a shortage occurring under the Preferred Alternative for the period 2027 through 2060 would range from a low of 397 jobs during a 500,000 af shortage in 2060 to a high of 1,181 jobs during a 1.8 maf shortage in 2040 (Table 4.14-3). Losses in personal income would range from a low of approximately $12.3 million to a high of approximately $43.5 million (Table 4.14-3).

For the period 2027 through 2060, a shortage of 500,000 af would have the greatest probability of occurring, ranging from 36 percent to 52 percent. Job losses during a 500,000 af shortage would range from 397 jobs in 2060 to 552 jobs in 2027. Losses in personal income would range from $12.3 million to $17.3 million (Table 4.14-3). Even if considered to be permanent, these changes in jobs and personal income are not considered substantial because the changes represent less than one percent of total employment and personal income within the six-county study area and Arizona.

The probabilities of shortages occurring under the Preferred Alternative in 2040 and 2060 are similar to the probabilities under the No Action Alternative. The probability of a 500,000 af shortage occurring under the Preferred Alternative in 2027 is greater when compared to the No Action Alternative.

4.14.2.2 Changes in Tax Revenues in Arizona

This section describes the potential changes in tax revenue for each alternative as a result of changes in agricultural production. Changes in tax revenue would result from the direct reduction in agricultural production, from reduced business-to-business activity, and from reductions in personal income. The tax revenue discussion summarizes the impacts for those Arizona counties that may experience a water shortage resulting in changes in agricultural production. The results of the county-level assessment on tax revenues for each shortage amount, year, and county are provided in Appendix H. The counties analyzed are Maricopa, Pinal, Pima, Mohave, La Paz, and Yuma. A summary comparison of the effects on tax revenue is provided at the end of this subsection.

Table 4.14-4 presents a comparison of the shortage amounts with the estimated changes in tax revenues and lists the probabilities of occurrence for each alternative. Shortages generated by the alternatives that were not exactly equal to the amounts shown in Table 4.14-4 were counted at the next highest value for the probabilities listed in Table 4.14-4.

Table 4.14-4
Estimated Reduction in Tax Revenues as a Result of Shortages to Agricultural Lands Under the Action Alternatives and the No Action Alternative by Selected Year and Shortages

Shortage Amount (af)	2017						
	Shortage Probabilities for Each Alternative (percent)						Changes in Tax Revenues ($ million)
	NA	BS	CBS	WS	RS	PA	
400,000	-	-	-	2	-	-	(7.7)
500,000	45	15	-	-	-	16	(8.2)
600,000	-	13	-	-		8	(9.7)
800,000	-	3	-	-	18	3	(10.6)
1,000,000	-	-	1	-	16	-	(11.6)
1,200,000	1	-	-	-	2	-	(14.8)
1,800,000	-	-	-	-	-	-	-
2,500,000	-	-	-	-	-	-	-
Shortage Amount (af)	2026						
	Shortage Probabilities for Each Alternative (percent)						Changes in Tax Revenues ($ million)
	NA	BS	CBS	WS	RS	PA	
400,000	-	-	-	12	-	-	(4.6)
500,000	34	15	1	-	-	24	(5.9)
600,000	-	13	-	-	-	11	(6.4)
800,000	7	7	3	-	18	6	(7.4)
1,000,000	6	-	2	-	14	-	(8.5)
1,200,000	1-	-	-	-	5	-	(13.5)
1,800,000	-	-	-	-	-	-	-
2,500,000	-	-	-	-	-	-	-
Shortage Amount (af)	2027						
	Shortage Probabilities for Each Alternative (percent)						Changes in Tax Revenues ($ million)
	NA	BS	CBS	WS	RS	PA	
400,000	-	-	-	-	-	-	-
500,000	38	48	44	37	38	50	(5.5)
600,000	1	-	-	1	-	-	(5.9)
800,000	3	2	2	3	-	-	(7.2)
1,000,000	2	-	2	2	-	1	(8.4)
1,200,000	1	-	1	-	-	-	(12.5)
1,800,000	3	-	-		-	-	(15.6)
2,500,000	-	1	-	3	-	-	(18.9)

Table 4.14-4
Estimated Reduction in Tax Revenues as a Result of Shortages to Agricultural Lands Under the Action Alternatives and the No Action Alternative by Selected Year and Shortages

Shortage Amount (af)	2040						
	Shortage Probabilities for Each Alternative (percent)						Changes in Tax Revenues ($ million)
	NA	BS	CBS	WS	RS	PA	
400,000	-	-	-	-	-	-	-
500,000	37	35	33	34	44	36	(4.6)
600,000	2	-	2	1	-	-	(5.0)
800,000	4	5	3	5	-	4	(6.0)
1,000,000	2	2	2	3	2	1	(7.6)
1,200,000	2	3	7	3	1	4	(9.3)
1,800,000	3	3	2	3	2	3	(14.6)
2,500,000	-	-	-	-	-	-	-
Shortage Amount (af)	**2060**						
	Shortage Probabilities for Each Alternative (percent)						Changes in Tax Revenues ($ million)
	NA	BS	CBS	WS	RS	PA	
400,000	-	-	-	-	-	-	-
500,000	54	52	50	51	534	52	(4.2)
600,000	1	1	3	2	1	1	(4.6)
800,000	4	6	6	4	4	6	(7.0)
1,000,000	3	1	1	2	1	1	(7.8)
1,200,000	3	3	4	3	4	3	(8.8)
1,800,000	3	3	3	3	3	3	(14.1)
2,500,000	-	-	-	-	-	-	-

Note:
NA = No Action Alternative
WS = Water Supply Alternative
CBS = Conservation Before Shortage Alternative
BS = Basin States Alternative
RS = Reservoir Storage Alternative
PA = Preferred Alternative
- = No Shortage Occurring

Arizona reported a total of $8.477 billion in state taxes collected and $5.943 billion in local government taxes collected for 2001 through 2002 (http://ftp2.census.gov/govs/estimate/02slsstab1a.xls). These values are compared to the tax impacts associated with the action alternatives and the No Action Alternative, discussed in the following paragraphs, as referred to in Table 4.14-4 and in Appendix H.

No Action Alternative. Potential decreases in tax revenue occurring under the No Action Alternative for the period 2008 through 2026 would range from a low of $5.9 million during a 500,000 af shortage in 2026 to a high of $14.8 million during a 1.2 maf shortage in 2017. For the period 2008 through 2026, a shortage of approximately 500,000 af would have the greatest probability of occurring, estimated at 45 percent in 2017 and 34 percent in 2026.

Potential decreases in tax revenue for the period 2027 through 2060 would range from a low of $4.2 million during a 500,000 af shortage in 2060 to a high of $18.9 million during a 2.5 maf shortage in 2027. For the period 2027 through 2060, a shortage of 500,000 af would have the greatest probability of occurring, estimated at between 37 percent in 2040 to 54 percent in 2060. These changes in tax revenues represent less than 0.2 percent total state taxes collected and less than 0.3 percent of local taxes collected.

Basin States Alternative. Potential decreases in tax revenue occurring under the Basin States Alternative for the period 2008 through 2026 would range from a low of $5.9 million during a 500,000 af shortage in 2026 to a high of $10.6 million during an 800,000 af shortage in 2017. For the period 2008 through 2026, a shortage of 500,000 af would have the greatest probability of occurring, estimated at 15 percent.

Potential decreases in tax revenue attributable to a shortage occurring under the Basin States Alternative during the period 2027 through 2060 would range from a low of $4.2 million during a 500,000 af shortage in 2060 to a high of $18.9 million during a 2.5 maf shortage in 2027. For the period 2027 through 2060, a shortage of 500,000 af would have the greatest probability of occurring, estimated at between 35 percent in 2040 to 52 percent in 2060. These changes in tax revenues represent less than 0.3 percent of total state taxes collected and less than 0.4 percent of local taxes collected.

Conservation Before Shortage Alternative. This analysis assumes that the voluntary conservation targets (400 kaf, 500 kaf, and 600 kaf at Lake Mead elevations 1,075 feet msl, 1,050 feet msl, and 1,025 feet msl, respectively) would be met and therefore only the potential impacts of involuntary shortages were analyzed. Potential decreases in tax revenue due to an involuntary shortage occurring under the Conservation Before Shortage Alternative during the period 2008 through 2026 would range from a low of $5.9 million during a 500,000 af shortage in 2026 to a high of $11.6 million during a 1 maf shortage in 2017. For the period 2008 through 2026, a shortage of 800,000 af would have the greatest probability of occurring, estimated at only three percent.

Potential decreases in tax revenue attributable to a shortage occurring under the Conservation Before Shortage Alternative during the period 2027 through 2060 would range from a low of $4.2 million during a 500,000 af shortage in 2060 to a high of $1.6 million during a 1.8 maf shortage in 2040. For the period 2027 through 2060, a shortage of 500,000 af would have the greatest probability of occurring, estimated at between 33 percent in 2040 to 50 percent in 2060. These changes in tax revenues represent less than 0.2 percent of total state taxes collected and less than 0.3 percent of local taxes collected.

Water Supply Alternative. Potential decreases in tax revenue occurring under the Water Supply Alternative during the period 2008 through 2026 would range from a low of $4.6 million during a 400,000 af shortage in 2026 to a high of $7.7 million during a 400,000 af shortage in 2017. For the period 2008 to 2026, only shortages of 400,000 af would occur, ranging from two percent in 2017 to 12 percent in 2026. This lack of shortages is a result of this alternative's strategy to provide full water deliveries until no water remains in Lake Mead, a reservoir draw down situation which has a low probability of occurring during the interim period.

Potential decreases in tax revenue attributable to a shortage occurring under the Water Supply Alternative during the period 2027 through 2060 would range from a low of $4.2 million during a 500,000 af shortage in 2060 to a high of $18.9 million during a 2.5 maf shortage in 2060. For the period 2027 through 2060, a shortage of 500,000 af would have the greatest probability of occurring, estimated at between 37 percent in 2027 to 51 percent in 2060. These changes in tax revenues represent less than 0.3 percent of total state taxes collected and less than 0.4 percent of local taxes collected.

Reservoir Storage Alternative. Potential decreases in tax revenue attributable to a shortage occurring under the Reservoir Storage Alternative during the period 2008 through 2026 would range from a low of $7.4 million during an 800,000 af shortage in 2026 to a high of $14.8 million during a 1.2 maf shortage in 2017. For the period 2008 through 2026, a shortage of 800,000 would have the greatest probability of occurring, estimated at 18 percent in 2017 and 2026.

Potential decreases in tax revenue attributable to a shortage occurring under the Reservoir Storage Alternative during the period 2027 through 2060 would range from a low of $4.2 million during a 500,000 af shortage in 2060 to a high of $14.6 million during a 1.8 maf shortage in 2040. For the period 2027 through 2060, a shortage of 500,000 af would have the greatest probability of occurring, estimated at between 38 percent in 2027 to 53 percent in 2060. These changes in tax revenues represent less than 0.2 percent of total state taxes collected and less than 0.3 percent of local taxes collected.

Preferred Alternative. Potential decreases in tax revenue attributable to a shortage occurring under the Preferred Alternative during the period 2008 through 2026 would range from a low of $5.9 million during 500,000 af shortage in 2026 to a high of $10.6 million during an 800,000 af shortage in 2017. For the period 2008 through 2026, a shortage of 500,000 af would have the greatest probability of occurring, estimated at 16 percent in 2017 and 24 percent in 2026.

Potential decreases in tax revenue attributable to a shortage occurring under the Preferred Alternative during the 2027 through 2060 would range from a low of $4.2 million during a 500,000 in 2060 to a high of $14.6 million during a 1.8 maf shortage in 2040. For the period 2027 through 2060, a shortage of 500,000 af would have the greatest probability of occurring, estimated at between 36 percent in 2040 to 52 percent in 2060. These changes in tax revenues represent less than 0.2 percent of total state taxes collected and less than 0.3 percent of local taxes collected.

4.14.2.3 Changes in Agricultural Production in California and Resulting Changes in Employment and Income in California

The results of the water allocation modeling indicate that although a portion of the shortages may be shared by California, agricultural users and production would only be affected by a very large shortage. However, agricultural production in California would not be adversely affected because any shortage amount would be very small. None of the alternatives are expected to result in a substantial change in California's agricultural production.

4.14.2.4 Changes in Agricultural Production in Nevada and Resulting Changes in Employment and Income in Nevada

The results of the water allocation modeling indicate that although a portion of the shortages may be shared by Nevada, agricultural users would not be affected in the event a shortage occurs. There are very few agricultural users that receive part of Nevada's Colorado River water allocation. None of the alternatives are expected to result in a change in Nevada's agricultural production.

Shortages occurring in Nevada are expected to be limited to the M&I sector. No changes in employment and income as a result of changes in agricultural production in Nevada are expected under any of the alternatives.

4.14.3 Potential Impacts to Municipal and Industrial Water Users

This section provides the results of the assessment of potential changes in M&I water use and resulting socioeconomic effects. The analysis is a qualitative discussion supported by the assessment of the shortage probabilities and volumes described in Section 4.4, Tables 4.4-5 through 4.4-8, Table 4.4-15, and in Appendix G.

For the period 2008 through 2060 the probability of a shortage occurring is highest for shortages ranging from 400,000 to 800,000 af and the probabilities of shortages occurring greater than 800,000 af are very similar among all the alternatives, including the No Action Alternative. Accordingly, the focus of the M&I analysis is to describe the effects of shortages that range from 400,000 af to 800,000 af.

For the period 2008 through 2026, the shortages under the No Action Alternative, the Basin States, Conservation Before Shortage, and Reservoir Storage Alternatives, and the Preferred Alternative would have the highest probability of occurring. In 2017, a 500,000 af shortage would have a 45 percent chance of occurring under the No Action Alternative compared to a 16 percent chance under the Preferred Alternative; the alternative with the highest probability of a shortage occurring among the action alternatives. Conversely, a 600,000 af shortage would have a greater likelihood of occurring under the Basin States, Conservation Before Shortage, and Reservoir Storage Alternatives as compared to the No Action Alternative and the Water Supply Alternative.

For the period 2027 through 2060, the probability of a shortage occurring under each alternative is highest at the 500,000 af shortage level. When compared to the No Action Alternative, shortages of 500,000 af in 2060 have a greater probability of occurring under all the action alternatives. Conversely, in 2027 and in 2040 shortages of 500,000 af have a similar probability of occurring under all the alternatives.

4.14.3.1 Changes in Municipal and Industrial Water Uses In Arizona

This section describes the potential socioeconomic effects that would result from changes in deliveries to M&I users in Arizona. The analysis is based on an analysis of shortage amounts in the range of 400,000 af to 800,000 af.

Arizona's Drought Management Plan serves as an umbrella that provides direction to Arizona state agencies and guidance to regional and local agencies regarding responses to drought conditions (Arizona Drought Task Force 2004). 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. Shortages to the Arizona M&I sector would be addressed through each entity's supply-side and demand-side drought response actions and programs.

In 2017, Arizona M&I shortages would range from approximately 9,200 af during a 400,000 af shortage to 176,000 af during an 800,000 af shortage. In 2026, Arizona M&I shortages would range from approximately 99,000 af during a 400,000 af shortage to 176,000 af during an 800,000 af 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.

4.14.3.2 Changes in Municipal and Industrial Water Uses In California

The section provides the results of the analysis of changes of potential socioeconomic effects as a result of changes in deliveries to M&I users. The conclusions are based on information provided in Section 4.4 of this Final EIS. In summary, deliveries to MWD are not anticipated to be adversely affected for Lower Basin shortages up to 1.8 maf because of California's higher Colorado River water supply priority relative to Arizona's and Nevada's Colorado River water supply priorities. In addition, shortages of 1.8 maf or greater have a low probability of occurring. MWD has or is working on putting in place storage and transfer programs that are expected to provide full supplies when needed even when Colorado River surplus supplies are not available. Examples of MWD actions include agreements with irrigation districts and individual landowners to reduce water use by fallowing lands, funding water efficiency improvements, and banking and exchange programs.

MWD is not expected to experience a substantial reduction in deliveries to M&I users during a shortage because of the priority of California's water rights in combination with the availability of alternative water supplies. The action alternatives are not expected to result in a substantial change in economic activities dependent on M&I deliveries.

4.14.3.3 Changes in Municipal and Industrial Water Uses in Nevada

This section describes the potential socioeconomic effects that would result from changes in deliveries to M&I users in Nevada. The analysis is based on a comparison of the action alternatives to the No Action Alternative.

Shortages to the M&I sector of Southern Nevada would mostly be borne by the SNWA, which has prepared a drought plan (SNWA 2005) to address water shortages. That plan includes two levels; a drought watch, and a drought alert and calls for landscape watering restrictions to private lawns, community use recreational turf areas, and golf courses. The plan also includes restrictions on surface, building, equipment, and vehicle washing.

Between 2008 and 2027, action alternatives would result in shortage allocations that are both less than or greater than those under the No Action Alternative. Although the largest differential would occur under the Water Supply Alternative in 2027, where the maximum shortage would equal approximately 279,000 af as compared to 60,548 af under the No Action Alternative, this shortage amount is the result of the unlikely event that Lake Mead elevation would fall below the SNWA intake. Under the Preferred Alternative, maximum shortages would decrease by 15,000 af in 2017 and increase to approximately 45,000 af in 2026. For each shortage scenario, the probability of shortages in southern Nevada would not be substantially different than under the No Action Alternative, with the exception of the 500,000 af shortage. The probability of a 500,000 af shortage occurring under any of the action alternatives would be substantially lower when compared to the No Action Alternative (Tables 4.4-5 and 4.4-6). In addition, with Nevada's drought plan in place, shortages to the M&I sector (under the No Action Alternative or under either of the action alternatives) would be managed. Socioeconomic effects on southern Nevada's M&I sector would vary depending on the size of the shortage, but the probability of larger shortages (greater than 600 kaf) which have the potential for more impacts, is not substantially different between the No Action Alternative and the Preferred Alternative.

4.14.4 Potential Impacts to Recreation

This section describes the changes in reservoir-related and river-related economic activity attributable to implementing the action alternatives. The assessment is based, in part, on the conclusions provided in Section 4.3 and Section 4.12.

4.14.4.1 Change in Economic Activity as a Result of Changes in Recreation Occurring at Lake Powell

The following qualitative assessment of changes in recreation-related economic activity is based on a comparison of Lake Powell elevations modeled for the No Action Alternative and for each action alternative.

As shown in Figure 4.14-2, at the 90th percentile there are no differences in Lake Powell end-of-September elevations between the alternatives. This suggests that at higher lake elevations there would be no differences in recreation opportunities and associated economic activity among the alternatives.

At the 50th percentile, end-of-September reservoir elevations under the Reservoir Storage Alternative would be nearly the same as those under the No Action Alternative. This suggests that recreation opportunities and resulting economic activity would not change. Reservoir elevations would be lower under the Conservation Before Shortage, Basin States, and Water Supply Alternatives, and the Preferred Alternative when compared to the No Action Alternative, with the Water Supply Alternative showing the lowest 50th percentile elevations. Because the reservoir would have substantial storage under all alternatives at the 50th percentile, these lower elevations are not expected to result in substantial change in recreation opportunities at Lake Powell and would not result in a substantial change in recreation-related economic activity.

The greatest differences in Lake Powell elevations would occur at the 10th percentile. Lake Powell elevations would be higher under the Reservoir Storage Alternative when compared to the No Action Alternative. These higher elevations would benefit recreation opportunities at Lake Powell and resulting economic activity. Reservoir levels would be nearly the same under the Basin States and Conservation Before Shortage Alternatives, the Preferred Alternative, and the No Action Alternative. This suggests that recreation-related economic activity would be the same among these four alternatives. Reservoir elevations would be lowest under the Water Supply Alternative and would result in the greatest adverse effect on recreation opportunities and associated reduction in economic activity.

4.14.4.2 Change in Economic Activity as a Result of Changes in Recreation Occurring in the Colorado River Downstream of Lake Powell

Recreation opportunities and use would not be adversely affected on the Colorado River reach downstream of Lake Powell because flows would not drop below safe boating thresholds for all of the alternatives. There would be no resulting changes in recreation-related economic activity among the alternatives because recreation use is not expected to change.

4.14.4.3 Change in Economic Activity as a Result of Changes in Recreation Occurring at Lake Mead

The following qualitative assessment of changes in recreation-related economic activity is based on a comparison of Lake Mead elevations modeled for the No Action Alternative and each action alternative.

As illustrated in Figure 4.14-3, at the 90th percentile there are essentially no differences in Lake Mead end-of-July elevations among the alternatives. This suggests that at the higher lake elevations there would no differences in recreation opportunities and associated economic activity.

At the 50th percentile, end-of-July reservoir elevations under the Reservoir Storage Alternative would be higher when compared to the No Action Alternative. This suggests that recreation opportunities and resulting economic activity would be greater under the Reservoir Storage Alternative. Reservoir levels for the Basin States and Conservation Before Shortage Alternatives, the Preferred Alternative, and the No Action Alternative would be nearly the same. No substantial differences in economic activity would occur under the Conservation Before Shortage, Basin States, and Water Supply alternatives, and the Preferred Alternative.

The greatest differences in Lake Mead elevations would occur at the 10th percentile. Lake Mead elevations under the Basin States, Conservation Before Shortage, and Water Supply alternatives, and the Preferred Alternative would be slightly higher during the interim period when compared to the No Action Alternative. This suggests that there would be only a small, if any, increase in economic activity when compared to the No Action Alternative. The Reservoir Storage Alternative would result in the greatest increase in Lake Mead elevations compared to the No Action Alternative. These higher elevations would benefit recreation opportunities and resulting economic activity.

4.14.4.4 Changes in Economic Activity as a Result of Changes in Recreation Occurring in the Colorado River Downstream of Lake Mead

Recreation opportunities and use would not be adversely affected on the reach of the Colorado River downstream of Lake Mead because daily and hourly releases from Hoover Dam, Davis Dam, Parker Dam, and Imperial Dam would remain within historical ranges. As a result, there would be no change in recreation-related economic activity among the alternatives because recreation opportunities and use are not expected to change.

4.14.5 Potential Impacts of Multi-Year Shortages

An analysis was conducted to estimate the magnitude and probability of shortages occurring during two or more consecutive years (Section 4.4 and Appendix P). The analysis suggests that during the interim period, there is a high probability that multi-year shortages for volumes greater than or equal to 400,000 af may occur. The No Action Alternative has the highest probability of multi-year shortages and the Water Supply Alternative has the lowest probability (zero percent) during the interim period. Of the five action alternatives, the Reservoir Storage Alternative has the highest probability of multi-year shortages. After the end of the interim period, the probability of a multi-year shortages occurring would be very similar among all the alternatives.

A multi-year shortage could result in a higher probability of a permanent loss in employment, income, and tax revenue if the same agricultural operations or M&I uses experience a shortage over consecutive years. Because it is not known how a multi-year shortage would be allocated over a specific water delivery area, the potential magnitude of longer-term socioeconomic effects cannot be estimated. However, as indicated in the multi-year shortage graphs provided in Section 4.4 and in Appendix P, the probabilities of multi-year shortages occurring would typically be less than under the No Action Alternative. This suggests that the probability of longer-term adverse socioeconomic effects occurring under the action alternatives would be less when compared to the No Action Alternative.

4.14.6 Potential Impacts of a Voluntary Conservation Program

An assessment was performed of the positive and negative impacts of implementing a voluntary conservation program (Appendix H) as postulated in the Conservation Before Shortage Alternative. The compensation to farmers under a voluntary fallowing program could potentially offset some of the adverse socioeconomic effects of reducing agricultural production. The degree to which these payments would offset the adverse socioeconomic effects of fallowing agricultural lands would depend on the payment schemes and amounts associated with a particular program. Instituting a voluntary fallowing program could result in positive economic effects. However, as suggested by the results of the two scenarios described in Appendix H, estimating the socioeconomic effects of implementing a program with a reasonable degree of certainty is difficult without additional detail regarding payment amounts, geographic location, and timing. There are many variables that need to be considered and these will vary widely by region, programs size, length of program, and participating entities.

4.14.7 Summary

4.14.7.1 Employment, Income, and Tax Revenues

Although a loss in employment and income could potentially occur under any of the action alternatives, the probability of any shortage occurring would be greater under the No Action Alternative. This suggests that the potential loss in employment, income, and tax revenues estimated for the No Action Alternative would be reduced under each of the action alternatives. The probabilities of any shortage amount occurring would be similar under all the action alternatives during the interim period with the exception of the Water Supply Alternative. When compared to the other action alternatives, the probabilities of any shortage amount occurring would be lower under the Water Supply Alternative. This indicates that, with the exception of the Water Supply Alternative, the potential losses in employment, income, and tax revenues would be similar among the action alternatives during the interim period. However, none of the changes in employment and income are considered substantial when compared to total employment and income generated within the study area.

For the period 2027 through 2060, the change in employment and income would be similar between the No Action Alternative and the action alternatives. The greatest difference would be in 2027 in which the probabilities would be slightly higher when compared to those under the No Action Alternative. However, by 2040, the probabilities of shortages occurring under all of the alternatives are very similar.

4.14.7.2 Municipal and Industrial Water Uses

Adverse effects on employment and income in Arizona and Nevada during shortages would be minimized as a result of drought plans being in place. No adverse effects are expected in California because of priority of apportionment and the availability of alternative water supplies.

4.14.7.3 Recreation

Recreation opportunities and associated economic activity at Lake Powell are not expected to be substantially different under the No Action Alternative, the Basin States and Conservation Before Shortage Alternatives, and the Preferred Alternative. Recreation opportunities and associated economic activity could potentially be adversely affected under the Water Supply Alternative due to the potentially lower Lake Powell elevations that may occur under this alternative. Conversely, recreation opportunities and associated economic activity would benefit under the Reservoir Storage Alternative as a result of potentially higher Lake Powell elevations under this alternative.

Recreation opportunities and associated economic activity at Lake Mead are not expected to be substantially different under the No Action Alternative, the Basin States, Conservation Before Shortage, and Water Supply alternatives, and the Preferred Alternative. Recreation opportunities and associated economic activity could potentially benefit under the Reservoir Storage Alternative due to the potentially higher Lake Mead elevations that may occur under this alternative.

Because daily and hourly flows in the Lake Powell to Lake Mead reach and in the Colorado River reaches downstream of Lake Mead would likely remain within ranges suitable for boating, there would be no change in river-related economic activity.

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4.15 Environmental Justice

This section describes the methods of analysis, and potential effects on environmental justice communities at the county level. The twelve environmental justice counties that were identified in Section 3.15 are: Coconino, La Paz, Mohave, Pima, Pinal, and Yuma counties in Arizona; Imperial, Los Angeles, Orange, Riverside, and San Bernardino counties in California; and San Juan County in Utah.

4.15.1 Methodology

The twelve environmental justice counties were examined by resource to identify whether any of the alternatives are likely to have disproportionate and adverse human health or environmental impacts.

4.15.2 Hydrology, Water Deliveries, and Socioeconomics

Potential water shortages will not impact water deliveries in Utah (Section 4.4) and would only rarely affect water deliveries in California (Table 4.4-21 and Table 4.4-22). Six of the eight Arizona counties are environmental justice communities. Two of the three counties served by the CAP are environmental justice communities (Pinal and Pima). Under all alternatives, a Lower Basin shortage would cause the reduction of water deliveries first to the CAP and other post-1968 Colorado River contractors in Arizona. While some would consider this a disproportionate impact on these Arizona counties as compared to other Colorado River contractors, this water entitlement priority is mandated under the CRBPA, and would occur under all of the action alternatives as well as under the No Action Alternative.

As an example of the magnitude of potential socioeconomic impacts, in 2026 a 500,000 af shortage has a 34 percent chance of occurring under the No Action Alternative. This would potentially result in a loss of about 561 jobs in Arizona (Table 4.14-3). In comparison, under the Preferred Alternative, the probability of occurrence is approximately 24 percent and would result in a loss of the same number of jobs. Under the Basin States Alternative, the probability of this shortage volume in 2026 is approximately 15 percent. Under the Conservation Before Shortage and the Water Supply alternative, there would be a one percent and zero percent probability of this occurrence, respectively. Under the Reservoir Storage Alternative, there is a zero percent probability of this shortage volume in 2026. The biggest difference in the probability of shortage occurs in 2017 with an 18 percent probability of occurrence of an 800,000 af shortage under the Reservoir Storage Alternative and a zero percent probability of occurrence under the No Action Alternative. Even so, this effect is projected to only result in the loss of approximately 860 jobs in Arizona. The loss in the number of jobs is so small compared to the total number of jobs in the environmental justice counties that the effects of the alternatives are negligible.

Accordingly, there is no substantive difference among the alternatives with respect to environmental justice impacts from water deliveries and socioeconomics.

4.15.3 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. For example, in Imperial County, California, the predicted salinity values would range from 732 mg/L to 783 mg/L. All values are below the 879 mg/L numeric criterion established by the Colorado River Basin Salinity Control Forum (Section 4.5).

4.15.4 Air Quality

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 to the other counties. Likewise, there would be no significant difference among alternatives at Lake Mead or downstream. Therefore, the proposed federal action would not result in any disproportionate effects to environmental justice communities.

4.15.5 Visual Resources

Potential impacts to visual resources were considered for attraction features, calcium carbonate rings, and sediment deltas. While some of these features are located within San Juan County, Utah, (e.g., Rainbow Bridge) an environmental justice community, effects are not disproportionate or unique to any environmental justice community.

4.15.6 Biological Resources

Potential impacts to biological resources would not disproportionately impact any environmental justice community identified within the study area. Potential impacts to vegetation, wildlife, and fish due to the action alternatives would be minor.

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.

4.15.7 Cultural Resources

Potential impacts or access to cultural resources are not expected to be unique to the environmental justice communities identified in the study area. Reclamation and the cooperating agencies are committed to compliance with all laws and regulations associated with historic properties, sacred sites, and cultural resources. Consultations are ongoing with concerned Indian tribes.

4.15.8 Indian Trust Assets

Reclamation has concluded that the proposed federal action will 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.

4.15.9 Electrical Power Resources

Changes to electrical power production among the alternatives have the potential to affect environmental justice communities disproportionately through possible minor increases in electricity rates resulting from decreased electrical power generation under some of the action alternatives. However, these changes in electrical power production are generally very minor (less than one percent) and the facilities potentially affected produce less than four percent of the total power produced in the region. Therefore no substantial environmental justice effects are anticipated.

4.15.10 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.

4.15.11 Transportation

Potential transportation impacts are associated with ferry services on Lake Powell and on the Colorado River downstream of Davis Dam. At Lake Powell, both San Juan County and Kane County would be equally affected by any disruption to the ferry service due to low reservoir elevations. San Juan County would not be disproportionately affected. Downstream of Davis Dam, the ferry service across the river serves two non-environmental justice counties.

4.15.12 Summary

After evaluating each resource, it is concluded that the environmental justice communities identified in the study area would not be disproportionately affected by any of the anticipated environmental impacts stemming from the proposed federal action. Nor would the proposed federal action result in adverse disproportionate impacts on human health within these environmental justice communities.

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4.16 Indirect Effects of Intentionally Created Surplus Mechanism

Indirect effects are reasonably foreseeable environmental impacts which are caused by the proposed federal action, but may occur later in time or farther removed in distance. This section describes the potential indirect effects from Reclamation's proposed creation of the ICS mechanism as part of the proposed federal action. Potential cumulative effects of other related non-ICS projects are described in Chapter 5.

Several Colorado River water users have expressed preliminary interest in proposing ICS projects in the future, but the projects are not sufficiently formulated to include in this indirect effect analysis. The types of proposed projects that are being contemplated include: (1) fallowing, (2) tail-water recovery systems, (3) seepage interception, (4) ground-water desalination, (5) canal lining, (6) crop rotation, (7) importation of non-system water, (8) integrated information systems, and (9) scientific irrigation scheduling. Such future ICS proposals will be proposed and considered for approval in accordance with the operational guidelines to be adopted in the ROD[1].

SNWA proposes three ICS projects which were specifically formulated to utilize the ICS mechanism. It is anticipated that creation of ICS and subsequent delivery of water from Lake Mead for these currently proposed projects will be approved as part of the ROD. While the proposed SNWA ICS projects are not federal projects, they will rely on Reclamation's approval for creation, accounting, and delivery of water from Lake Mead. The effects of these projects within the geographic scope of the proposed federal action have been included in the modeling assumptions and are therefore included in the various resource analyses in the Final EIS. The localized impacts of these ICS projects (outside the geographic scope of the proposed federal action) are described here as indirect effects of Reclamation's establishment of the ICS mechanism.

The currently proposed ICS projects addressed in this section include:

- SNWA Virgin River and Muddy River Tributary Conservation;
- SNWA Coyote Spring Well and Moapa Transmission System Project; and
- Lower Colorado River Drop 2 Storage Reservoir Project.

Each of these currently proposed projects is described below.

[1] Reclamation has included draft guidelines in the Final EIS (Appendix S) that discuss the administration of ICS.

4.16.1 ICS Projects Directly Related to Creation of ICS Mechanism

4.16.1.1 SNWA Virgin River and Muddy River Tributary Conservation

As part of an ongoing initiative to protect southern Nevada from drought and augment future water supplies, SNWA proposed a project in 2004 to develop surface flows from the Virgin River and Muddy River for which it holds water rights. The SNWA currently holds water right Permit 58591 (priority date 1989) and Permit 57643 (priority date 1993) for a total not to exceed annual diversion from the Virgin River of 190 kaf, and also owns pre-BCPA water rights in the form of shares which were purchased from irrigation companies on the Virgin River and Muddy River.

SNWA would utilize pre-BCPA Virgin River and Muddy River water rights by retiring the rights from their current use and allowing them to flow into Lake Mead for recovery for municipal and industrial purposes, also known as Tributary Conservation ICS. Tributary Conservation is a form of ICS where water rights on Colorado River tributaries within the Lower Basin states that have been used for a significant period of years and were perfected prior to June 25, 1929 (the effective date of the BCPA) could be retired and allowed to flow into the Colorado River mainstream. Under the proposed federal action, the Lower Basin state that provides such Tributary Conservation could then recover the amount of water contributed through Tributary Conservation for municipal or industrial purposes only.

Pre-BCPA water rights on the Virgin River have a priority date of pre-1905 and were decreed by the Nevada Supreme Court in 1927. The decree allocated 17,785 afy to the Bunkerville and Mesquite Irrigation Companies. SNWA currently owns shares in the Bunkerville Irrigation Company representing approximately 3,700 afy of surface water rights, but does not currently own any shares in the Mesquite Irrigation Company. On the Muddy River, water rights were decreed in 1920 and that decree allocated the entire flow of the Muddy River. On the lower Muddy River, the entire flow is diverted by the Muddy Valley Irrigation Company for agricultural use. SNWA currently owns shares in the Muddy Valley Irrigation Company representing approximately 7,000 afy of pre-BCPA surface water rights. On the upper Muddy River, SNWA leases approximately 1,000 afy from the Church of Jesus Christ of Latter-Day Saints (LDS Church). The LDS Church lease is for a term of 20 years, with an option to renew the lease for an additional 20 years.

SNWA has been purchasing pre-BCPA water rights on the Virgin River and Muddy River since 1997 in an effort to reduce SNWA's dependence on the Colorado River and to develop additional water supplies for Southern Nevada. SNWA's purchase and retirement of pre-BCPA water rights will allow for assured flows within the entire Muddy River and the portion of the Virgin River downstream of the Bunkerville and Mesquite Irrigation Companies by using flows that were historically consumptively used off channel by agriculture for the creation of Tributary Conservation ICS.

4.16.1.2 SNWA Coyote Spring Well and Moapa Transmission System Project

This project involves the development of groundwater production and conveyance facilities for groundwater from Coyote Spring Valley in Clark County, Nevada. The purpose of the Coyote Spring Well and Moapa Transmission System Project is to develop and convey SNWA's existing 9,000 afy of Coyote Spring Valley water rights in an efficient and practical manner to locations where such water can be placed to a beneficial use by SNWA and/or Moapa Valley Water District. This project would increase diversification of SNWA's current water resources to include non-Colorado River water resources.

SNWA applied to BLM for a Right of Way for the project facilities in November 2002. The application required BLM to prepare an EA which was initiated in July 2003. The Final EA and FONSI for the project were issued in June 2007.

4.16.1.3 Lower Colorado River Drop 2 Storage Reservoir Project

The lower Colorado River Drop 2 Storage Reservoir Project is one of many potential actions that will be taken to maximize beneficial use of Colorado River water in the United States. Reclamation issued a draft EA on November 30, 2006 for public review. The specific objectives of the proposed Drop 2 Storage Reservoir Project include:

- providing additional storage capacity to reduce non-storable flows of the Colorado River below Parker Dam; and
- providing additional operational flexibility in the lower Colorado River system for the Imperial Irrigation District, Coachella Valley Water District, and other Colorado River system users.

The Drop 2 Storage Reservoir Project has three primary physical components: 1) the reservoir itself; 2) an inlet canal; and 3) an outlet canal:

- **Reservoir.** Two 4,000 af capacity reservoir cells would be formed by excavating below the existing ground surface. The approximate depth of the reservoir would be 20 feet. The reservoir would occupy approximately 621 acres.
- **Inlet Canal.** The inlet canal would be from five to seven miles in length depending on alignment. Inlet canal capacity would be 1,700 cfs.
- **Outlet Canal.** The outlet canal would be approximately 3,500 feet in length, connecting the reservoir to the AAC near Drop 2 Reservoir Project. Outlet canal capacity would be 1,700 cfs.

The Drop 2 Storage Reservoir Project operations would be relatively simple: a new inlet canal would convey water from the existing Coachella Canal Turnout on the AAC to a new storage reservoir, and as needed, water would be returned to the AAC via a new outlet canal. Both the inlet and outlet canals would be designed to use gravity flow.

Recent legislation passed by Congress in late 2006[2] requires that the Secretary proceed "without delay" with the "construction, operation and maintenance" of the Drop 2 Storage Reservoir Project. Reclamation published a Final EA on the project and made it available to the public on June 20, 2007. Construction is scheduled to begin in 2008.

4.16.2 Impacts by Resource

4.16.2.1 Hydrologic Resources and Water Delivery

The SNWA Virgin River and Muddy River Tributary Conservation are projected to result in up to 30,000 af of additional water being delivered to Lake Mead annually from the Virgin River and the Muddy River. Approximately one-third of this amount is expected to come from the Virgin River and two-thirds from the Muddy River. This is consistent with the flow volumes that were analyzed in the Final EIS and the additional flow volumes from the Virgin River and Muddy River analyzed in the LCR MSCP for effects to Lake Mead.

The retired agricultural water rights will be conveyed to Lake Mead via the Overton Arm in one of two fashions. Water will be diverted from the Colorado River through its historic point of diversion, flow through irrigation company ditches, and return to the mainstream Colorado River further downstream if the flow is necessary in the irrigation company ditches to avoid impacts to the irrigation company's operations or wildlife. This is the proposed operation for waters thus far acquired in the Bunkerville Irrigation Company and Muddy Valley Irrigation Company. Alternatively, if the water is not associated with an irrigation company or not required for the purposes described above, it will not be diverted and instead will remain in the channel and allowed to flow to the mainstream Colorado River. Additional information on the hydrology of the Lower Virgin River and Muddy River is provided in Appendix R.

The effects to lower Virgin River and Muddy River hydrology are detailed in Appendix R. In the Virgin River, the 10,000 afy of Tributary Conservation represents less than 7 percent of the historic annual flow in the Virgin River at Halfway Wash. Given the relative magnitudes of flow, and the complex geology and underflow that occur in the floodplains along the entire Virgin River, it is questionable whether there would be any noticeable change in surface flows on the Virgin River from this project. Upper Muddy River surface water flow is measured at the Moapa and Glendale gages, which average

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[2] The full text of the legislation, contained in Public Law 109-432 provides:
: "SEC. 396. REGULATED STORAGE WATER FACILITY.
(a) CONSTRUCTION, OPERATION, AND MAINTENANCE OF FACILITY.—
Notwithstanding any other provision of law, upon the date of enactment of this Act, the Secretary shall, without delay, pursuant to the Act of January 1, 1927 (44 Stat. 1010, chapter 47) (commonly known as the ''River and Harbor Act of 1927''), as amended, design and provide for the construction, operation, and maintenance of a regulated water storage facility (including all incidental works that are reasonably necessary to operate the storage facility) to provide additional storage capacity to reduce nonstorable flows on the Colorado River below Parker Dam.
(b) LOCATION OF FACILITY.—
The storage facility (including all incidental works) described in subsection (a) shall be located at or near the All American Canal."

approximately 30,000 afy. The current leased SNWA water rights in the upper Muddy River (1,000 afy) represent approximately 3 percent of the gages' flow, well within a typical gage margin of error of 10 percent and virtually undetectable. In the lower Muddy River, the surface flows are measured at the Overton Gage which averages approximately 9,000 afy. This gage reflects surface water flows reaching Lake Mead. While there have been no studies confirming irrigation system losses to the alluvium, it is believed that there is water bypassing the Overton Gage as underflow. Because of irrigation system losses and substantial underflow bypassing the gage, simply subtracting the Moapa-Glendale Gage readings from the Overton Gage readings will not provide an accurate accounting of the volume of Tributary Conservation flow reaching Lake Mead. Like the Virgin River and upper Muddy River, the complex geology, gaging accuracies and historic use of this water will make it difficult to see a marked increase in the Overton Gage from Tributary Conservation flows. Due to all the factors mentioned above, 20,000 afy of Tributary Conservation is not likely to result in a noticeable change to flows on the Muddy River from the current conditions. Additional information on the effects to river hydrology is provided in Appendix R.

The hydrologic impacts on Lake Mead from additional inflows from the Virgin River and Muddy River, and additional water deliveries to SNWA, were included in the modeling assumptions and are described in Chapter 4.3 of the Final EIS. Impacts of the Virgin River and Muddy River tributary conservation projects are described in this section.

The development of Coyote Spring Well and the Moapa Transmission System would similarly result in increased flows into Lake Mead. The project would develop and convey SNWA's existing 9,000 afy of Coyote Spring Valley water rights for delivery into the mainstream of the Colorado River. These hydrologic effects were also included in the modeling conducted for this EIS. For the reasons described above, the positive effect on river flow would be subtle, if noticeable at all.

The Drop 2 Storage Reservoir Project would result in a reduction in the non-storable flows that are delivered to Mexico. The Drop 2 Storage Reservoir Project was included in the hydrologic modeling for Lake Mead and the Colorado River conducted for this EIS, and any resulting impacts are included in the analysis in Sections 4.3 and 4.4. The EA for the Drop 2 Storage Reservoir Project included a specific analysis of the hydrologic impacts of the project on smaller (non-flood release) flows in the limitrophe division of the Colorado River. The EA concluded decreases in surface water flows passing Morelos Diversion Dam would not conflict with 1944 Treaty delivery obligations, or substantially alter the existing drainage pattern or flows of the limitrophe reach. The slight decrease in flows could potentially adversely affect groundwater levels, but the change does not represent a significant impact to groundwater supplies.

4.16.2.2 Water Quality

No significant impacts on water quality in the Virgin River and the Muddy River are anticipated from the SNWA Tributary Conservation. For the reasons described immediately above, the changes in river flow, while positive, would be within a typical gage margin of error of ten percent and virtually undetectable. Potential water quality impacts of the Drop 2 Storage Reservoir Project on the Colorado River were included in the modeling assumptions, and are included in the analysis in Section 4.5. The localized short-term and long-term water quality impacts of the Drop 2 Storage Reservoir Project were considered in the Reclamation EA and determined not to be significant, with implementation of mitigation measures, such as construction of sediment traps (e.g., hay bales, silt fences, straw wattles) and temporary desilting basins for onsite erosion control.

4.16.2.3 Air Quality

Any effect from SNWA's development of pre-BCPA water rights on the Virgin River and the Muddy River, the development of the Coyote Spring Well and the Moapa Transmission System, and the Drop 2 Storage Reservoir Project on Lake Mead was taken into account in the modeling performed for this project, and any impacts of wind blown dust from exposed reservoir shoreline is included in the analysis in Section 4.6. SNWA's Virgin River and Muddy River Tributary Conservation project has the potential to contribute to air quality concerns through the retirement of agricultural lands. However, this concern is mitigated by the gradual implementation of the full project. Moreover, some of the water rights that SNWA purchased may have already been regularly fallowed or out of production at the time they were acquired by SNWA. The air quality effects of the Coyote Spring Well and the Moapa Transmission System were considered in the BLM EA and determined not to be significant because construction emissions would cease at the completion of construction and will be mitigated by implementation of an approved dust control plan. Air emissions from the Drop 2 Storage Reservoir Project were estimated in the Reclamation EA for the project and determined not to be significant. Project air emissions from both construction and operation and maintenance activities would remain below all emission significance thresholds would produce no significant air quality impacts.

4.16.2.4 Visual Resources

The potential impact of SNWA's development of pre-BCPA water rights on the Virgin River and the Muddy River, the development of the Coyote Spring Well and the Moapa Transmission System, and the Drop 2 Storage Reservoir Project related to the exposure of the calcium carbonate ring around Lake Mead was included in the modeling for Lake Mead elevations, as described in Section 4.7. SNWA's Virgin River and Muddy River Tributary Conservation would not result in visual impacts because, as described above, the increased flows in the two rivers would likely not be noticeable. Visual impacts from the Coyote Spring Well and the Moapa Transmission System were considered in the BLM EA and determined not to be significant because SNWA will mitigate visual effects by restoring the pipeline right-of-way and using best management practices to reduce the line and form contrast of the regulating tank by application of color, reduction of height, reduction of size, and addition of architectural features. Construction emissions from the Drop 2 Storage Reservoir Project were considered in the Reclamation EA and determined not to be significant. The location for the Drop 2 Storage Reservoir Project is a former working farm and the location has no visually unique characteristics. As this site is presently void of any significant visual feature, and as the nearby open space areas would remain unchanged from existing conditions, construction and operation under the Drop 2

Storage Reservoir River Project would not degrade the existing visual character or quality of the site and its surroundings.

4.16.2.5 Biological Resources

In general, increased flow from the SNWA Virgin River and Muddy River Tributary Conservation is expected to have a beneficial, albeit minor, effect on any marsh or riparian habitat along the Muddy River or within the Mormon Mesa area on the Virgin River. No effect is anticipated on the Virgin River above the Bunkerville Irrigation Company service area, as acquisition of surface water rights will take place below this area.

Drought has been identified as one type of event that could create conditions that can impact sensitive fish species on the Lower Virgin River and the Muddy River. The assured flows in the Virgin River and the Muddy River proposed by the SNWA Tributary Conservation Program are expected to have a beneficial effect on fish and bird species because they may help lessen the effects of drought (Bio-West Inc. 2007). While drought tends to decrease river flows, the Tributary Conservation flows are expected to act as an assured baseflow for sensitive fish and bird species on the Muddy River and below the Bunkerville Irrigation Company service area on the Virgin River. Potential effects to species within Lake Mead from increased flows from the Virgin River and the Muddy River are described in Section 4.8 and were addressed in the LCR MSCP. More detailed information on the existing biological resources along the Virgin River and the Muddy River and potential project impacts is provided in Appendix R. The Coyote Spring Well and the Moapa Transmission System would have similar, but proportionately smaller benefits to biological resources. Other biological impacts from the Coyote Spring Well and the Moapa Transmission System were considered in the BLM EA and determined not to be significant because any impacts to species will be mitigated through the Clark County Multiple Species Habitat Conservation Program and conservation measures implemented through the Biological Opinion for the project. Restoration of the right-of-way will minimize impacts to vegetation.

The Drop 2 Storage Reservoir Project will reduce the amount of non-storable flows that arrive at Morelos Diversion Dam, resulting in reduced frequency of a portion of these flows in the limitrophe reach of the Colorado River. These and other impacts to biological resources from the Drop 2 Storage Reservoir Project were described in the Reclamation EA for the project and determined not to be significant. Because the habitat where the storage reservoir would be constructed is already relatively disturbed, the development would not result in a significant adverse effect on vegetation and wildlife habitat.

Reductions in non-storable flows to Morelos Diversion Dam would not significantly affect riparian communities and associated wildlife of the limitrophe. Based on results of groundwater modeling, the potential impacts on marsh habitats from potential changes in minimum groundwater levels are considered not significant. Potential impacts on occupied southwestern willow flycatcher habitat are considered not significant. The implementation of the proposed compensation and the conservation of habitat will fully mitigate impacts to the flat-tailed horned lizard.

4.16.2.6 Cultural Resources

SNWA's Virgin River and Muddy River Tributary Conservation would not result in impacts to cultural resources because, as described above, the increased flows in the two rivers would not cause effects outside their normal channels. Further, because the surface water rights acquired are not appurtenant to specific land parcels, there would be no way to associate the water rights acquisition to specific land use changes. Cultural resource impacts from the Coyote Spring Well and the Moapa Transmission System were considered in the BLM EA and determined not to be significant because no impacts to historic properties or paleontological resources are proposed and impacts to one cultural resource site has been mitigated by implementation of an archeological site treatment plan. Reclamation considered cultural resources for the Drop 2 Storage Reservoir Project as part of its EA. Mitigation or avoidance will be implemented for the four historic properties which may be either directly or indirectly affected by the proposed project. There would be no significant residual impacts to cultural resources.

4.16.2.7 Indian Trust Assets

SNWA's Virgin River and Muddy River Tributary Conservation would not result in impacts to ITAs because, as described above, the increased flows in the two rivers would not cause effects outside their normal channels. Further, because the surface water rights acquired are not appurtenant to specific land parcels, there would be no way to associate the water rights acquisition to specific land use changes. No ITAs were identified by BLM in the area affected by the Coyote Spring Well and the Moapa Transmission System. No Indian tribes, groups, or individuals have identified any specific ITAs during the public notification or scoping process. Therefore, no impacts to ITAs are anticipated from implementation of the project. Reclamation considered ITAs for the Drop 2 Storage Reservoir Project as part of its EA and determined that none would be affected. The Drop 2 Storage Reservoir Project would augment Reclamation's ability to meet its obligations to Colorado River water users, including the Quechan Tribe.

4.16.2.8 Electrical Power

SNWA's development of pre-BCPA water rights on the Virgin River and the Muddy River, the development of the Coyote Spring Well and the Moapa Transmission System, and the Drop 2 Storage Reservoir Project would result in limited impacts to power production. These projects were included in the hydrologic modeling for the EIS, and the potential impacts of these changes on power production are included in Section 4.11. None of the projects would have significant effects on electrical power resources in the local project areas.

4.16.2.9 Recreation

SNWA's Virgin River and Muddy River Tributary Conservation would not result in impacts to recreational activities because the increased flows in the two rivers would be small. Potential impacts to recreational activities from the Coyote Spring Well and the Moapa Transmission System were considered in the BLM EA and determined not to be significant. Reclamation considered potential recreation impacts for the Drop 2 Storage

Reservoir Project as part of its EA and determined that the Drop 2 Storage Reservoir Project would have impacts during the construction period through temporary closure of BLM trails, and some access roads to recreation areas. These temporary closures were determined not to be a significant impact on recreation.

4.16.2.10 Transportation

SNWA's Virgin River and Muddy River Tributary Conservation would not result in impacts to transportation because the two rivers are not used for transportation. Potential impacts to transportation from the Coyote Spring Well and the Moapa Transmission System were considered in the BLM EA and determined not to be significant because there are currently low levels of traffic in the vicinity and construction traffic impacts would cease at the end of construction activity. Reclamation considered potential transportation impacts for the Drop 2 Storage Reservoir Project as part of its EA and determined that the Drop 2 Storage Reservoir Project would have temporary, insignificant impacts to area roadways during its construction period. Impacts would be mitigated by implementation of traffic management plan and other measures. The outlet canal would be installed as a pipe underneath Interstate 8 (I-8). This construction has the potential to require temporary closure of some travel lanes of I-8. During the Drop 2 Storage Reservoir Project construction Reclamation will direct the contractor to maintain at least one eastbound travel lane and one westbound travel lane on I-8 (or the functional equivalent using detours).

4.16.2.11 Socioeconomics

SNWA has been purchasing pre-BCPA water rights on the Virgin River and the Muddy River since 1997, in an effort to reduce SNWA's dependence on the Colorado River and to develop additional water supplies for Southern Nevada. As of July 1, 2007, SNWA has acquired water rights from Virgin River and Muddy River sources that will yield an average annual water supply of approximately 11,700 af. SNWA anticipates acquiring a total of approximately 30,000 afy of pre-BCPA water rights from entities with rights on the Virgin River and the Muddy River. Water rights historically used for agriculture along these two rivers are being voluntarily sold or leased to willing buyers, including buyers not associated with SNWA. Sometimes the water rights are leased back for agricultural use with a provision that at the end of the lease term, the water rights will be retired and allowed to return to the river system. Socioeconomic impacts on the local communities are reduced by the gradual nature of the acquisition program. The gradual conversion of these agricultural water rights to other uses is ongoing and will continue regardless of the establishment of the ICS mechanism, and this particular project. The Coyote Spring Well, the Moapa Transmission System, and the Drop 2 Storage Reservoir Project will result in short-term economic benefits from the creation of jobs and purchases of materials, supplies, and services. These effects were considered in the two EA's for these projects. The Drop 2 Storage Reservoir Project would have no effect on agricultural production and related revenues within Imperial County.

4.16.2.12 Environmental Justice

SNWA's Virgin River and Muddy River Tributary Conservation would not result in disproportionately high and adverse human health and environmental impacts to low-income or minority populations. The acquisition of surface water rights is from willing sellers and provides an economic benefit to the sellers. No environmental justice impacts were identified in the BLM EA for the Coyote Spring Well and the Moapa Transmission System. Reclamation considered environmental justice impacts for the Drop 2 Storage Reservoir Project as part of its EA and determined there would be no disproportionate impacts to low-income or minority populations.