3.3 RIVER SYSTEM OPERATIONS

This section addresses the operation of the Colorado River system, the modeling process used to simulate river operation and potential changes that may occur from implementation of the interim surplus criteria. The term *system management* refers to how the water is managed once it enters the Colorado River system and includes operation of the system reservoirs, dams and other Colorado River system facilities. The environmental and socioeconomic effects of the interim surplus criteria alternatives stem from changes in the operation of the Colorado River system under the surplus alternatives relative to the baseline conditions.

3.3.1 OPERATION OF THE COLORADO RIVER SYSTEM

Operation of the Colorado River system and delivery of Colorado River water to the seven Basin States and Mexico are conducted in accordance with the *Law of the River* as discussed in Section 1.3.2.1. Water cannot be released from storage unless there is a reasonable beneficial use for the water unless required for flood control or dam safety. Water is released from the system in time to satisfy the water delivery orders and to meet other valued uses and benefits, including power production. The principal facilities that were built to manage the water in the Colorado River System include Glen Canyon Dam and Hoover Dam.

The Colorado River system is operated by Reclamation pursuant to LROC and the AOP. The AOP is required by the CRBPA. The AOP is formulated for the upcoming year under a variety of potential scenarios or conditions. The plan is developed based on projected demands, existing storage conditions and probable inflows. The AOP is prepared by Reclamation, acting on behalf of the Secretary, in cooperation with the basin states, other Federal agencies, Indian tribes, state and local agencies and the general public, including governmental interests as required by Federal laws.

Prior to the beginning of the calendar year, Lower Basin diversion schedules are requested from water users entitled to Colorado River water as discussed in Section 3.4. These schedules are estimated monthly diversions and return flows that allow Reclamation to determine a tentative schedule of monthly releases through the Hoover Powerplant. Actual monthly releases are determined by the demand for water downstream of Hoover Dam. Daily changes in water orders are made to accommodate emergencies, temperature and weather.

A minimum of 1.5 maf is delivered annually to Mexico in accordance with the Treaty. The Treaty contains provisions for delivery of up to 200,000 acre-feet above the 1.5 maf coincident with Lake Mead flood control releases provided that the reasonable beneficial uses of the Lower Division states have been satisfied.

3.3.1.1 OPERATION OF GLEN CANYON DAM

Flows below Glen Canyon Dam are influenced by storage and release decisions that are scheduled and implemented on an annual, monthly and hourly basis from Glen Canyon Dam.

The annual volume of water released from Glen Canyon Dam is made according to the provisions of the LROC that includes a minimum objective release of 8.23 maf, storage equalization between Lake Powell and Lake Mead under prescribed conditions and the avoidance of spills. Annual releases from Lake Powell greater than the minimum occur if Upper Basin storage is greater than the storage required by Section 602(a) of the Colorado River Basin Project Act, and if the storage in Lake Powell is greater than the storage in Lake Mead. Annual release volumes greater than the minimum objective of 8.23 maf are also made to avoid anticipated spills.

Monthly operational decisions are generally intermediate targets needed to systematically achieve the annual operating requirements. The actual volume of water released from Lake Powell each month depends on the forecasted inflow, storage targets and annual release requirements described above. Demand for energy is also considered and accommodated as long as the annual release and storage requirements are not affected.

The National Weather Service Colorado Basin River Forecast Center (CBRFC) provides the monthly forecasts of expected inflow into Lake Powell. The CBRFC uses a satellite-telemetered network of hundreds of data collection points within the Upper Colorado River Basin that gather data on snow water content, precipitation, temperature and streamflow. Regression and real-time conceptual computer models are used to forecast inflows that are then used by Reclamation to plan future release volumes. Due to the variability in climatic conditions, modeling and data errors, these forecasts are based, in part, on large uncertainties. The greatest period of uncertainty occurs in early winter and decreases as the snow accumulation period progresses into the snowmelt season, often forcing modifications to the monthly schedule of releases.

An objective in the operation of Glen Canyon Dam is to attempt to safely fill Lake Powell each summer. When carryover storage from the previous year in combination with forecasted inflow allows, Lake Powell is targeted to reach a storage of about 23.8 maf in July (0.5 maf from full pool). In years when Lake Powell fills or nearly fills in the summer, releases in the late summer and early winter are generally made to draw the reservoir level down, so that there is at least 2.4 maf of vacant space in Lake Powell on January 1. Storage targets are always reached in a manner consistent with the LROC.

Scheduling of BHBF releases from Glen Canyon Dam are discussed in Section 3.6.2.2.

Daily and hourly releases are made according to the parameters of the ROD for the Glen Canyon Dam Final Environmental Impact Statement and published in the *Glen Canyon Dam Operating Criteria* (62 CFR 9447, Mar. 3, 1997), as shown in Table 3.3-1.

Table 3.3-1
Glen Canyon Dam Release Restrictions

Parameter	Cubic Feet per Second	Conditions
Maximum Flow[1]	25,000	
Minimum Flow	5,000	Nighttime
	8,000	7:00 a.m. to 7:00 p.m.
Ramp Rates		
Ascending	4,000	Per hour
Descending	1,500	Per hour
Daily Fluctuations[2]	5,000 to 8,000	

[1] To be evaluated and potentially increased as necessary and in years when delivery to the Lower Basin exceeds 8.23 maf.
[2] Daily fluctuation limit is 5,000 cfs for months with release volumes less than 0.6 maf; 6,000 cfs for monthly release volumes of 0.6 maf to 0.8 maf; and 8,000 cfs for monthly volumes over 0.8 maf.

3.3.1.2 OPERATION OF HOOVER DAM

Hoover Dam is managed to provide annual releases of at least 7.5 maf for consumptive use by the downstream United States users plus the United States' obligation to Mexico. Hoover Dam releases are managed on an hourly basis to maximize the value of generated power by providing peaking during high-demand periods. This results in fluctuating flows below Hoover Dam that can range from 1,000 cfs to 49,000 cfs. The upper range considers the maximum flow-through capacity through the powerplant at Hoover Dam is 49,000 cfs. However, because these flows enter Lake Mohave downstream, the affected zone of fluctuation is only a few miles.

Releases of water from Hoover Dam may also be affected by the Secretary's determinations relating to normal, surplus or shortage water supply conditions, as discussed in Section 1.3.4.1. Another type of release includes flood control releases. For Hoover Dam, flood control releases are defined in this DEIS as releases in excess of the downstream demands.

Flood control was specified as a primary project purpose by the BCPA, the act authorizing Hoover Dam. The Corps is responsible for developing the flood control operation plan for Hoover Dam and Lake Mead as indicated in 43 CFR 208.11. The plan is the result of a coordinated effort by the Corps and Reclamation. However, the Corps is responsible for providing the flood control regulations and has authority for final approval of the plan. Any deviations from the flood control operating instructions provided by the plan must be authorized by the Corps. The Secretary is responsible for operating Hoover Dam in accordance with these regulations.

Lake Mead's uppermost 1.5 maf of storage capacity, between elevations 1219.61 and 1229.0, is allocated exclusively for flood control. Within this capacity allocation, 1.218 maf of flood storage is above elevation 1221.0, which is the top of the raised spillway gates.

Flood control regulations specify that once Lake Mead flood releases exceed 40,000 cfs, the releases shall be maintained at the highest rate until the reservoir drops to elevation 1221.0 feet msl. Releases may then be gradually reduced to 40,000 cfs until the prescribed seasonal storage space is available.

The regulations set forth two primary criteria for address by flood control operations related to snowmelt: 1) preparatory reservoir space requirements, and 2) application of runoff forecasts to determine releases.

In preparation for each annual season of snow accumulation and associated runoff, progressive expansion of total Colorado River system reservoir space is required during the latter half of each year. Minimum available flood control space increases from 1.5 maf on August 1 to 5.35 maf on January 1. Required flood storage space can be accumulated within Lake Mead and in specified upstream reservoirs: Powell, Navajo, Blue Mesa, Flaming Gorge and Fontenelle. The minimum required to be reserved exclusively for flood control storage in Lake Mead is 1.5 maf. Table 3.3-2 presents the amount of required flood storage space building requirements within the Colorado River system by date:

Table 3.3-2
Minimum Required Colorado River System Storage Space

Date	Storage Volume (maf)
August 1	1.50
September 1	2.27
October 1	3.04
November 1	3.81
December 1	4.58
January 1	5.35

Normal space-building releases from Lake Mead to meet the required August 1 to January 1 flood control space are limited to a maximum of 28,000 cfs. Releases based on water entitlement holders' demand are much less than 28,000 cfs.

Between January 1 and July 31, flood releases, based on forecasted inflow, may be required to prevent filling of Lake Mead beyond its 1.5 maf minimum space requirement. Beginning on January 1 and continuing through July, the CBRFC issues monthly runoff forecasts. These forecasts are used by Reclamation in estimating releases from Hoover Dam. The release schedule contained in the Corps' regulations is based on increasing releases in six steps as shown on Table 3.3-3.

Table 3.3-3
Minimum Flood Control Releases at Hoover Dam

Step	Amount of Cubic Feet/Second
Step 1	0
Step 2	19,000
Step 3	28,000
Step 4	35,000
Step 5	40,000
Step 6	73,000

The lowest step, zero cfs, corresponds to times when the regulations do not require flood control releases. Hoover Dam releases are then made to meet water and power objectives. The second step, 19,000 cfs, is based on the powerplant capacity of Parker Dam. The third step, 28,000 cfs, corresponds to the 28,000 cfs Davis Dam Powerplant capacity. The fourth step in the Corps release schedule is 35,000 cfs. This flow corresponds to the powerplant capacity of Hoover Dam in 1987. However, the present powerplant capacity at Hoover Dam is 49,000 cfs. At the time Hoover Dam was completed, 40,000 cfs was the approximate maximum flow from the dam considered to be nondamaging to the downstream streambed. The 40,000 cfs flow now forms the fifth step. Releases of 40,000 cfs and greater would result from unusually large floods. The sixth and final step in the series (73,000 cfs) is the maximum controlled release from Hoover Dam that can occur without spillway flow.

Flood control releases are required when forecasted inflow exceeds downstream demands, available storage space at lakes Mead and Powell and allowable space in other Upper Basin reservoirs. This includes accounting for projected bank storage and evaporation losses at both lakes, plus net withdrawal from Lake Mead by the SNWA. The Corps regulations set the procedures for releasing the volume that cannot be impounded, as discussed above.

Average monthly releases are determined early in each month and apply only to the current month. The releases are progressively revised in response to updated runoff forecasts and changing reservoir storage levels during each subsequent month throughout the January 1–July 31 runoff period. If the reservoirs are full, drawdown is accomplished to vacate flood control space as required. Unless flood control is necessary, Hoover Dam is operated to meet downstream demands.

During non-flood operations, the end-of-month Lake Mead elevations are driven by downstream demands, Glen Canyon Dam releases and Mexican Water Treaty deliveries to Mexico. Lake Mead end-of-month target elevations are not fixed as are the end-of-month target elevations for Lake Mohave and Lake Havasu. Normally, Lake Mead elevations decline with increasing irrigation deliveries through June or later and then begin to rise again. Lake Mead's storage capacity provides for the majority of Colorado River regulation from Glen Canyon Dam to the border with Mexico.

3.3.2 NATURAL RUNOFF AND STORAGE OF WATER

Most of the natural flow in the Colorado River system originates in the Upper Basin and is highly variable from year to year. The natural flow represents an estimate of runoff flows that would exist without storage or depletion by man and was used in the modeling of the baseline conditions and interim surplus criteria alternatives. About 86 percent of the Colorado River System annual runoff originates in only 15 percent of the watershed—in the mountains of Colorado, Utah, Wyoming and New Mexico. While the average annual natural flow at Lees Ferry is calculated at 15.1 maf, annual flows in excess of 23 maf and as little as 5 maf have occurred. The flow in the Colorado River above Lake Powell reaches its annual maximum during the April through July period. During the summer and fall, thunderstorms occasionally produce additional peaks in the river. However, these flows are usually smaller in volume than the snowmelt peaks and of much shorter duration. Flows immediately below Glen Canyon Dam consist almost entirely of water released from Lake Powell. Downstream of Glen Canyon Dam, the annual river gains from tributaries, groundwater discharge and occasional flash floods from side canyons average 900,000 acre-feet. Immediately downstream of Hoover Dam, the river flows consist almost entirely of water released from Lake Mead. Downstream of Hoover Dam, the river gains additional water from perennial tributaries such as the Bill Williams River and the Gila River, groundwater discharge, and return flows.

Total storage capacity in the Colorado River system is nearly four times the river's average natural flow. The various reservoirs that provide storage in the Colorado River system and their respective capacities were discussed in Section 1.3.2.

Figure 3.3-1 presents an overview of the historical natural flow calculated at Lees Ferry for calendar years 1906 through 1999. The natural flow represents an estimate of the flows that would originate or exist above Lees Ferry without storage or depletion by man. This is different than the recorded or historical stream flows that represent actual measured flows. Figure 3.3-2 presents an overview of the historical flows recorded at Lees Ferry for the period 1922 through 1999 (calendar year).

Figure 3.3-1
Natural Flow at Lees Ferry Stream Gage

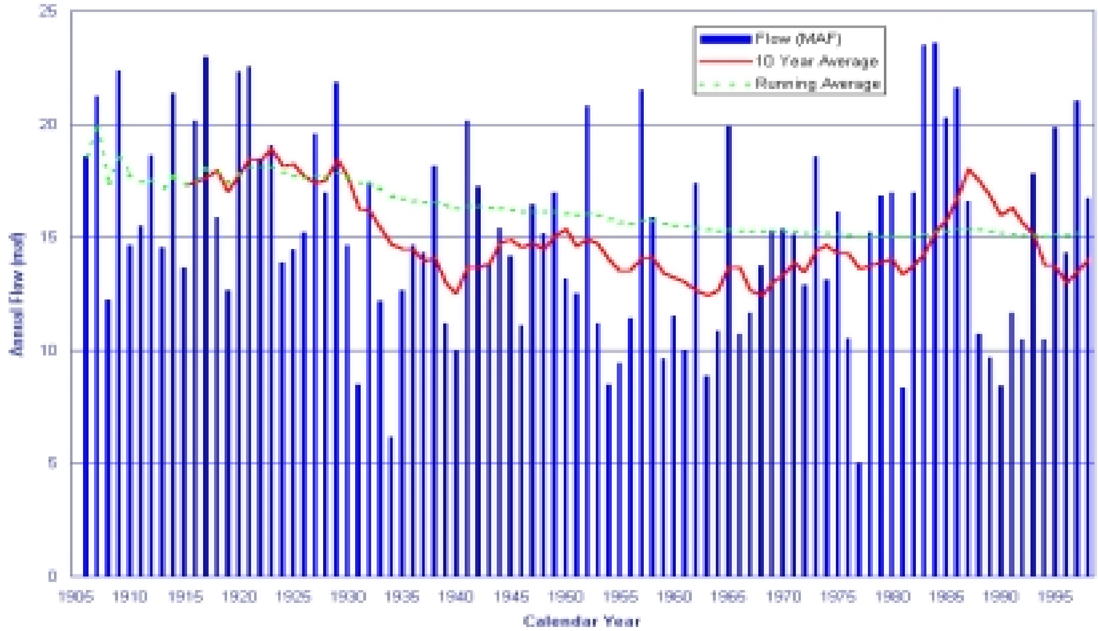
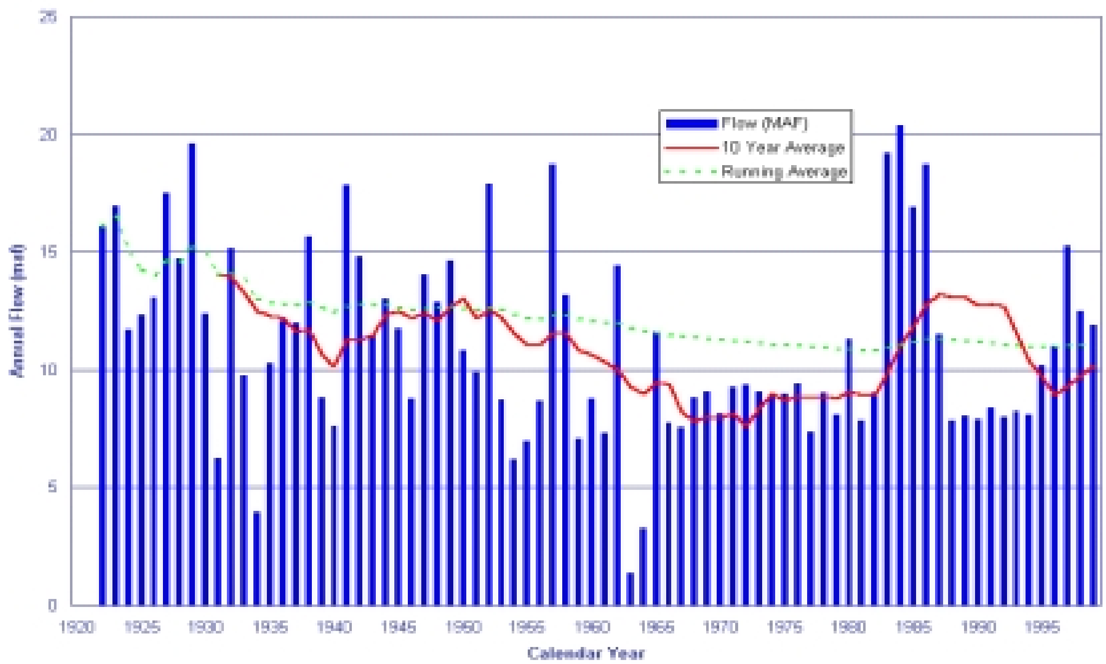


Figure 3.3-2
Historic Annual Flow at Lees Ferry Stream Gage



3.3.3 MODELING AND FUTURE HYDROLOGY

3.3.3.1 MODEL CONFIGURATION

Future Colorado River system conditions under baseline conditions and the surplus alternatives were simulated using a computerized model. The model framework used for this process is a commercial river modeling software called RiverWare. RiverWare was developed by the University of Colorado through a cooperative process with Reclamation and the Tennessee Valley Authority. RiverWare was configured to simulate the Colorado River System and its operation and integrates the Colorado River Simulation System (CRSS) model that was developed by Reclamation in the early 1970s. River operation parameters modeled and analyzed include the water entering the river system, storage in system reservoirs, releases from storage, river flows, and the water demands of and deliveries to the Basin States and Mexico.

The water supply used by RiverWare consists of the historic record of natural flow in the river system over the 85-year period from 1906 through 1990, from 29 individual inflow points on the system.

Future Colorado River water demands were based on demand and depletion projections prepared by the Basin States. Depletions are defined as diversions from the river less return flow credits, where applicable. Return flow credits are applied when a portion of the diverted water is returned to the river system. In cases where there are no return flow credits associated with the diversions, the depletion is equal to the diversion. The simulated operation of Glen Canyon Dam, Hoover Dam and other parts of the Colorado River system was consistent with applicable requirements for storage and flood control management, water supply deliveries to Mexico and flow regulation downstream of the system dams.

3.3.3.2 INTERIM SURPLUS CRITERIA MODELED

As discussed in Chapter 2, five operational scenarios are considered in this DEIS. The five scenarios considered and modeled consist of the baseline conditions and the surplus alternatives. The surplus alternatives consist of the Flood Control, Six States, California and the Shortage Protection alternatives.

Surplus deliveries to the Lower Division states and Mexico are provided under baseline conditions and all surplus alternatives. Common to baseline conditions and all alternatives, a surplus is declared when flood control releases are made from Lake Mead. Mexico receives surplus deliveries only under this condition.

3.3.3.3 GENERAL MODELING ASSUMPTIONS

Definitions and descriptions of the baseline conditions and the surplus alternatives and their operational criteria were provided in Chapter 2. The modeling of river system operations for the analysis presented in this DEIS also required certain assumptions about various aspects of water delivery and system operation. Some of the more important modeling assumptions are listed below.

Assumptions Common to Baseline and All Alternatives:

- The current Upper Basin reservoir operating rules are equivalent under all surplus alternatives and the baseline conditions.
- The Lake Mead flood control procedures would remain in effect.
- Reservoir starting conditions (all system reservoirs) are based on actual water level elevations recorded on January 1, 2000.
- The Upper Basin states' depletion projections as of 1996 are modeled.
- Water deliveries to Mexico are pursuant to the requirements of the Treaty. This provides minimum annual deliveries of 1.5 maf to Mexico and up to 1.7 maf under Lake Mead flood control release conditions.
- Lake Mead is operated to meet depletion schedules provided by the Lower Division states and Mexico.
- Lake Mohave and Lake Havasu are operated in accordance with their existing rule curves.
- There are no established shortage criteria that define when Lower Basin water users would receive shortage condition deliveries. However, the model is configured to provide approximately an 80 percent protection for the critical Lake Mead water elevation of 1083 feet msl (minimum power generation elevation).

Assumptions Specific to Surplus Alternatives:

The respective surplus criteria for the surplus alternatives are assumed to be effective for a specified period of 15 years. The effective period that was modeled is defined as the 15-year period beginning on January 1, 2001 and ending December 31, 2015. At the conclusion of the 15-year period, the modeled operating criteria for each of the surplus alternatives is assumed to revert to the operating criteria used to model baseline conditions.

- The conditions modeled for baseline conditions and the Flood Control Alternative do not include the implementation of the California 4.4 Plan.

The conditions modeled for the other surplus alternatives assume the implementation of the California 4.4 Plan.

- The surplus depletion schedules for Arizona, California and Nevada vary under each surplus alternative and the baseline conditions and are presented in Attachment G.

3.3.3.4 LAKE MEAD WATER LEVEL PROTECTION ASSUMPTIONS

There are no established shortage criteria for the operation of Lake Mead. However, it was necessary to include some shortage criteria in the model simulation to address concerns related to low Lake Mead water levels. Three important Lake Mead water elevations were selected for analysis. The significance of these selected elevations relates to known economic and/or socioeconomic impacts that would occur if Lake Mead water levels were lowered below the selected water levels. Elevation 1083 feet msl is the minimum water level for power generation at the Hoover Powerplant based on its existing turbine configuration. Elevation 1050 feet msl is the minimum water level necessary for operation of SNWA's upper water intake. Water withdrawn from the Colorado River through this intake is delivered to Las Vegas Valley, Boulder City and other parts of Clark County. Even though SNWA has constructed a second intake at a lower elevation, the original intake at elevation 1050 feet msl is needed to meet full SNWA summer diversions. Elevation 1000 feet msl is the minimum water level necessary for operation of SNWA’s lower water intake.

In the absence of specific shortage criteria, the Lake Mead level protection assumptions listed below were applied by the model to facilitate the evaluation of the baseline conditions and surplus alternatives.

First Level Shortage:

- The Lake Mead water level of 1083 feet msl was designated as a level that should be protected. Operation simulations were performed to develop a “protection line” to prevent the water level from declining below elevation 1083 feet msl with approximately an 80 percent probability. (The use of a 1050-foot protection line is illustrated in Attachment K.)
- A shortage would be determined to exist when the Lake Mead water level dropped below the protection line for elevation 1083 feet msl.
- During first level shortage conditions, the annual water delivery to CAP was set to 1.0 maf, and the SNWA was assigned 4 percent of the total shortage.

Second Level Shortage:

- A second level shortage would be determined to exist when the Lake Mead water surface elevation declined to 1000 feet msl.
- During second level shortage conditions, the CAP and SNWA consumptive use would be cut as needed to maintain the Lake Mead water level at 1000 feet msl. Once the delivery to the CAP is reduced to zero, deliveries to MWD and to Mexico would be cut to maintain the Lake Mead water level at 1000 feet msl. Cuts to MWD and Mexico were not observed to occur in the simulations conducted as part of this DEIS.

3.3.3.5 COMPUTATIONAL PROCEDURES

The model was used to simulate the future state of the Colorado River system on a monthly basis, in terms of reservoir levels, releases from the dams, hydroelectric energy generation, flows at various points along the system and diversions to and return flows from various water users. The input data for the model included the monthly tributary inflows, various physical process parameters (such as the evaporation rates for each reservoir) and the diversion and depletion schedules for entities in the Basin States and Mexico. The common and specific operating criteria were also input for each alternative being studied.

Despite the differences in the operating criteria for the baseline conditions and each surplus alternative, the future state of the Colorado River system (i.e., water levels at Lake Mead and Lake Powell) is most sensitive to the future inflows. As discussed in Section 3.3.2, observations over the period of historical record (1906–present) show that inflow into the system has been highly variable from year to year. Predictions of the future inflows, particularly for long-range studies, are highly uncertain. Although the model does not predict future inflows, it can be used to analyze a range of possible future inflows and to quantify the probability of particular events (i.e., lake levels being below or above certain levels).

Several methods are available for ascertaining the range of possible future inflows. On the Colorado River, a particular technique (called the Indexed Sequential Method) has been used since the early 1980s and involves a series of simulations, each applying a different future inflow scenario (USBR, 1985). Each future inflow scenario is generated from the historical natural flow record by "cycling" through that record. For example, the first simulation assumes that the inflows for 2000 through 2050 will be the 1906 through 1956 record, the second simulation assumes the inflows for 2000 through 2050 will be the 1907 through 1957 record, and so on. As the method progresses, the historical record is assumed to "wrap-around" (i.e., after 1990, the record reverts back to 1906), yielding a possible 85 different inflow scenarios. The result of the Indexed Sequential Method is a set of 85 separate simulations (referred to as "traces") for each operating criterion that is analyzed.

This enables an evaluation of the respective criteria over a broad range of possible future hydrologic conditions using standard statistical techniques, discussed in Section 3.3.3.6.

3.3.3.6 POST-PROCESSING AND DATA INTERPRETATION PROCEDURES

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

The model generates data on a monthly time step for some 300 points (or nodes) on the river system. Furthermore, through the use of the Indexed Sequential Method, the model generates 85 possible outcomes for each node for each month over the time period 2000 through 2050. These very large data sets are generated for each surplus alternative and baseline conditions and 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 are typically aggregated to reduce the volume of data and to facilitate comparing the alternatives to baseline conditions and to each other. The type of aggregation varies depending upon the needs of the particular resource analysis. The post-processing techniques used for this DEIS fall into two basic categories: those that aggregate in time, space or both, and those that aggregate the 85 possible outcomes.

For aggregation in time and space, simple techniques are employed. For example, deliveries of Colorado River water to all California diversion nodes in the model are summed to produce the total delivery to the state for each calendar year. Similarly, lake elevations may be chosen on a calendar year basis (end of December) to show long-term lake level trends as opposed to short-term fluctuations. Since the interim criteria period is 2000 through 2015, some analyses may suggest aggregating over that period of time and comparing the aggregation over the remaining years (2016 through 2050). The particular aggregation used will be briefly discussed in the methodology section for each resource.

Once the appropriate temporal and spatial aggregation is chosen, standard statistical techniques are used to analyze the 85 possible outcomes for a fixed time. Statistics that may be generated include the mean and standard deviation. However, the most common technique simply ranks the outcomes at each time (from highest to lowest) and uses the ranked outcomes to compute other statistics of interest. For example, if end-of-calendar year Lake Mead elevations are ranked for each year, the median outcome for a given year is the elevation for which half of the values are below and half are above (the median value or the 50th percentile value). Similarly, the elevation for which 10 percent of the values are less than or equal to, is the 10th percentile outcome.

Several presentations of the ranked data are then possible. A graph (or table) may be produced that compares the 90th percentile, 50th percentile, and 10th percentile outcomes from 2000 through 2050 for the baseline and all alternatives. It should be noted that a statistic such as the 10th percentile is not the result of any one hydrologic trace (i.e., no historical sequence produced the 10th percentile).

3.3.4 MODELING RESULTS

This section presents general and specific discussions of the Colorado River System operation modeling results. The following sequence of topics is used to address the potentially affected river system components:

- Lake Powell water levels,
- River flows between Glen Canyon Dam and Lake Mead,
- Lake Mead water levels, and
- River flows below Hoover Dam.

As noted previously, the potentially affected portion of the Colorado River system extends from Lake Powell to the NIB. Although lakes Mohave and Havasu are within the potentially affected area, it has been determined that the interim surplus criteria would have no affect on the operation of these facilities. The operation of lakes Mohave and Havasu is pursuant to monthly operating target elevations that are used to manage the storage and release of water and power production at these facilities. Under the respective target elevations, the water level fluctuation is approximately 14 feet for Lake Mohave and approximately four feet for Lake Havasu. Under all future operating scenarios considered under this DEIS, lakes Mohave and Havasu would continue to be operated under the current respective monthly target elevations.

3.3.4.1 GENERAL OBSERVATIONS CONCERNING MODELING RESULTS

The following general observations apply to the overall modeling and analyses results.

- Future water levels of lakes Powell and Mead will probably be lower than historical levels due to increasing Upper Basin depletions under the baseline conditions and the surplus alternatives. Of the four surplus alternatives, the Flood Control Alternative was shown to have the least tendency to reduce reservoir water levels. The Shortage Protection Alternative was shown to have the highest tendency to reduce reservoir water levels. The results of the baseline conditions are similar to those observed for the Flood Control Alternative. The results of the Six States and California alternatives fall between those of the baseline conditions and the Shortage Protection Alternative.

- Median Lake Mead elevations decline throughout the entire period of analysis for the baseline conditions and the surplus alternatives because depletions exceed long-term inflow. Median Lake Powell elevations decline for a number of years and then reverse. This reversal is observed for the baseline conditions as well as all surplus alternatives. The initial decline in Lake Powell for the baseline conditions and all surplus alternatives is related to increased Upper Basin depletions. For the Six State, California, and Shortage Protection alternatives, the decline is more pronounced due to Lower Basin surplus deliveries and associated equalization releases from Lake Powell. Lake Powell elevations eventually stabilize and begin to increase under the baseline conditions and all alternatives. This reversal is caused by less frequent equalization releases from Lake Powell (due to 602(a) storage) as the Upper Basin states increase their use of Colorado River water.
- The shortage protection line elevations used for this analysis were determined by a separate modeling study. That study used the CRSSez model, and the procedure followed is documented in the CRSSez User's Manual (USBR, May 1998). The use of the shortage protection line in this study resulted in slightly less (74 percent versus 80 percent) protection of Lake Mead water surface elevation 1083 feet msl than anticipated. This disparity is attributed to differences in modeling assumptions between the CRSSez model study and the current analysis and will be adjusted for the FEIS. However, because the current analysis used consistent shortage assumptions for baseline conditions and the surplus alternatives, the validity of relative comparisons is not compromised.
- To test the sensitivity of the results to the use of a 1083-foot protection level, model runs were also conducted with a protection level of 1050 feet msl. With the 1050-foot protection level, the water levels on Lake Mead in 2015 were essentially the same under the baseline condition and Flood Control Alternative; between 10 and 20 feet lower for the Shortage Protection and California alternatives; and intermediate for the Six State Alternative. Water level plots for reservoir levels with a 1050-foot Lake Mead protection level are in Attachment K.

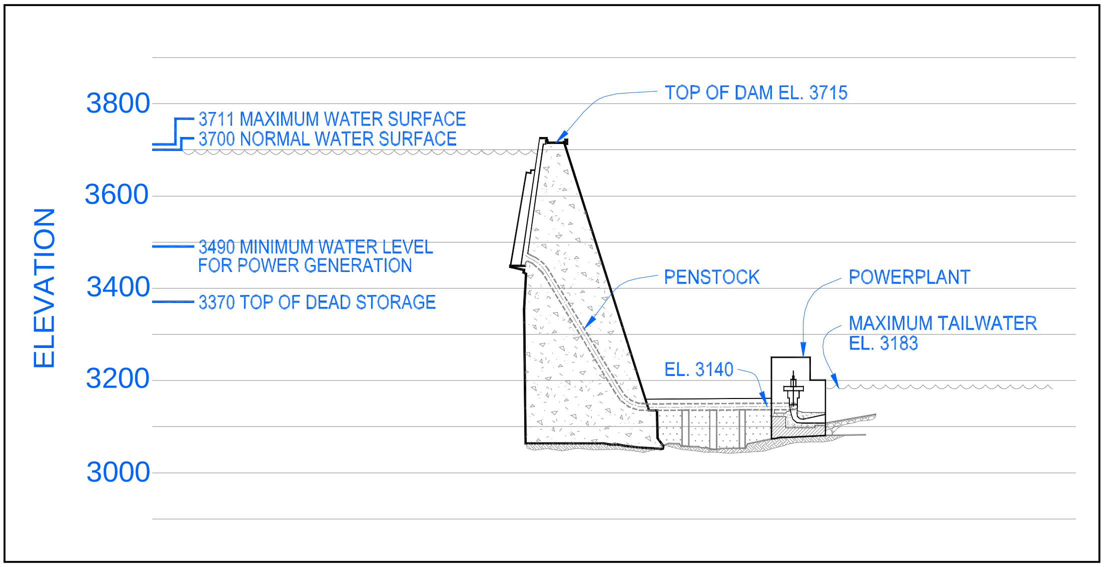
3.3.4.2 LAKE POWELL WATER LEVELS

3.3.4.2.1 Dam and Reservoir Configuration

Glen Canyon Dam is a concrete arch dam rising approximately 700 feet above the level of the Colorado River streambed. A profile of the dam is depicted on Figure 3.3-3.

Except during flood conditions, the "full reservoir" water level is 3700 feet msl, corresponding to the top of the spillway gates. Under normal operating conditions, releases from Glen Canyon Dam are made through the Glen Canyon Powerplant by means of gates on the upstream face of the dam. The minimum water level at which hydropower can be generated is elevation 3490 feet msl. Releases in excess of the powerplant hydraulic capacity may be made when flood conditions are caused by high runoff in the Colorado River Basin, or when needed to provide BHBF downstream of the dam, as is discussed in Section 3.6.

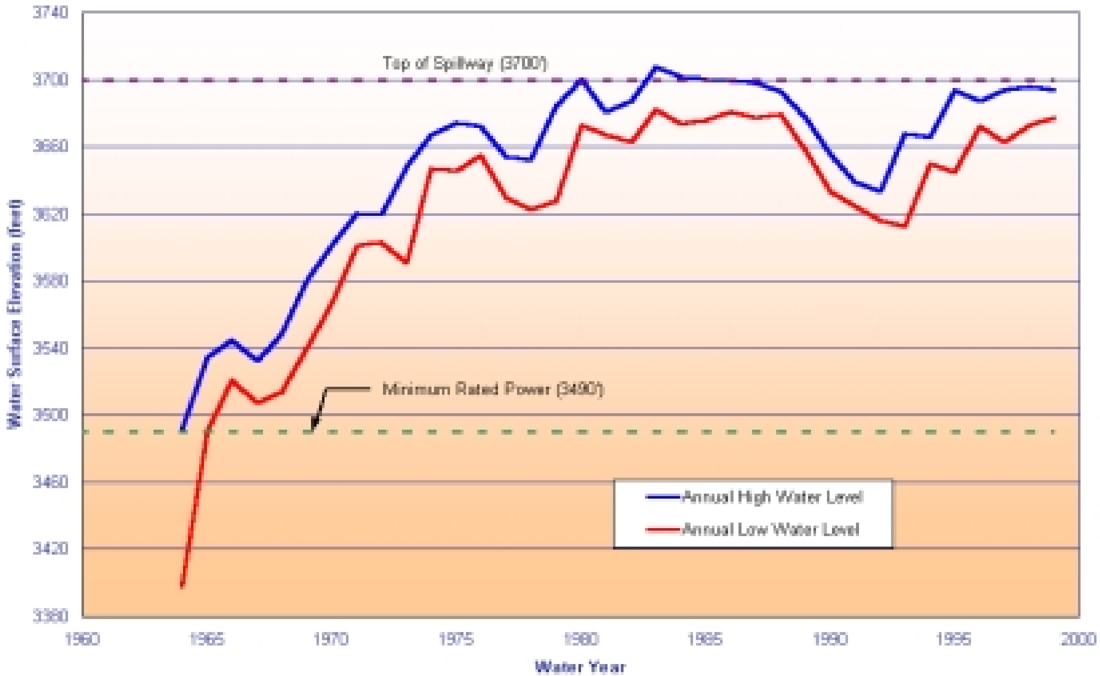
Figure 3.3-3
Lake Powell and Glen Canyon Dam Important Operating Elevations



3.3.4.2.2 Historic Water Levels

Glen Canyon Dam and Lake Powell were designed to operate from a normal maximum water surface elevation of 3700 feet msl to a minimum elevation of 3490 feet msl, the minimum for hydropower production. During flood conditions, the water surface elevation of Lake Powell can exceed 3700 feet msl by raising the spillway radial gates. Since first reaching equalization storage with Lake Mead in 1974, the reservoir water level has fluctuated from a high of 3708 feet msl to a low of approximately 3612 feet msl, as shown on Figure 3.3-4.

Figure 3.3-4
Historic Lake Powell Water Levels

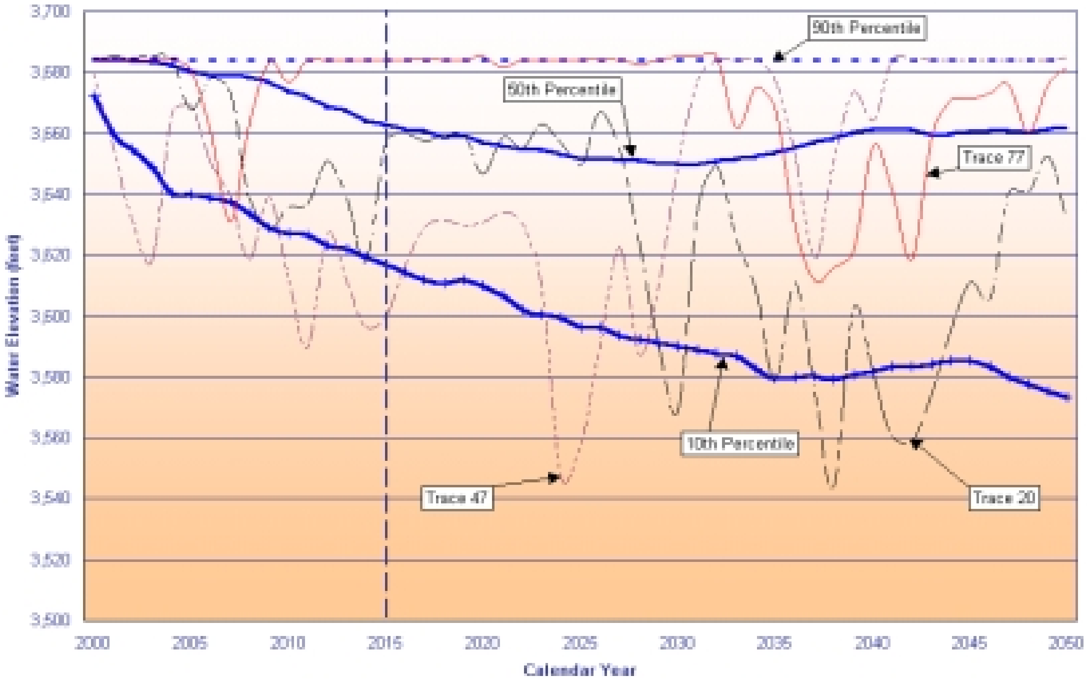


3.3.4.2.3 Baseline Conditions

The basic operating parameters for baseline conditions are described in Section 2.3.1 and the assumptions used for operational modeling purposes are described in Section 3.3.3.3. Under the baseline conditions, the water surface elevation of Lake Powell is projected to fluctuate between full level and decreasingly lower levels during the 50-year period of analysis (2001 to 2050).

Figure 3.3-5 illustrates the range of water levels by three lines, labeled 90th Percentile, 50th Percentile and 10th Percentile. The 50th percentile line shows the median water level for each future year. The median water level under baseline conditions is shown to decline to 3663 feet msl by 2015, declining further to a low of 3649 feet msl on 2031 and then increases to 3662 feet msl by 2050. The 10th percentile line shows there is a 10 percent probability that the water level would drop to 3617 feet msl by 2015 and to 3573 feet msl by 2050. Generally, there is about a 20-foot difference between the annual high and low water levels at Lake Powell. It should also be noted that the Lake Powell elevation at the end of the calendar year is near the seasonal low. The Lake Powell water level generally reaches its seasonal high in July.

Figure 3.3-5
Lake Powell End of Year Water Elevations Under Baseline Conditions
90th, 50th and 10th Percentile Values and Representative Traces



Three distinct traces were added to Figure 3.3-5 to illustrate what was actually simulated under the various traces and respective hydrologic sequences and also to highlight that the 90th, 50th and 10th percentile lines do not represent actual traces, but rather the respective ranking of the data from the 85 traces. The three traces illustrate the variability among the different traces and also illustrate how the reservoir levels could temporarily decline below the 10th percentile line. The trace identified as Trace 20 represents the hydrologic sequence that begins in year 1926. The trace identified as Trace 47 represents the hydrologic sequence that begins in year 1953. The trace identified as Trace 77 represents the hydrologic sequence that begins in year 1983.

In Figure 3.3-5, the 90th and 10th percentile lines bracket the probable range where 80 percent of future water levels simulated by the model for the baseline conditions would occur. This potential range would increase over time. The highs and lows shown on the three traces would likely be temporary conditions and the reservoir level would tend to fluctuate in the range through multiyear periods of above average and below average inflows. Neither the timing of water level variations between the highs and the lows, nor the length of time the water level would remain high or low can be predicted. These events would depend on the future variation in basin runoff conditions.

Figure 3.3-6 presents a comparison of the 90th, 50th and 10th percentile lines obtained for the baseline conditions to those obtained for the surplus alternatives. This figure is best used for comparing the relative differences in the general lake level trends that result from the simulation of the baseline conditions and surplus alternatives. As illustrated in Figure 3.3-6, the Flood Control Alternative is the alternative that could potentially result in the highest Lake Powell water levels. The Shortage Protection Alternative is the alternative that could potentially result in the lowest water levels. The baseline conditions yield slightly lower levels than the Flood Control Alternative, but the differences are very small. The results obtained under the Six States and California alternatives fall between the Flood Control and Shortage Protection alternatives.

Figure 3.3-6
Lake Powell End of Year Water Elevations
Comparison of Surplus Alternatives to Baseline Conditions
90th, 50th and 10th Percentile Values

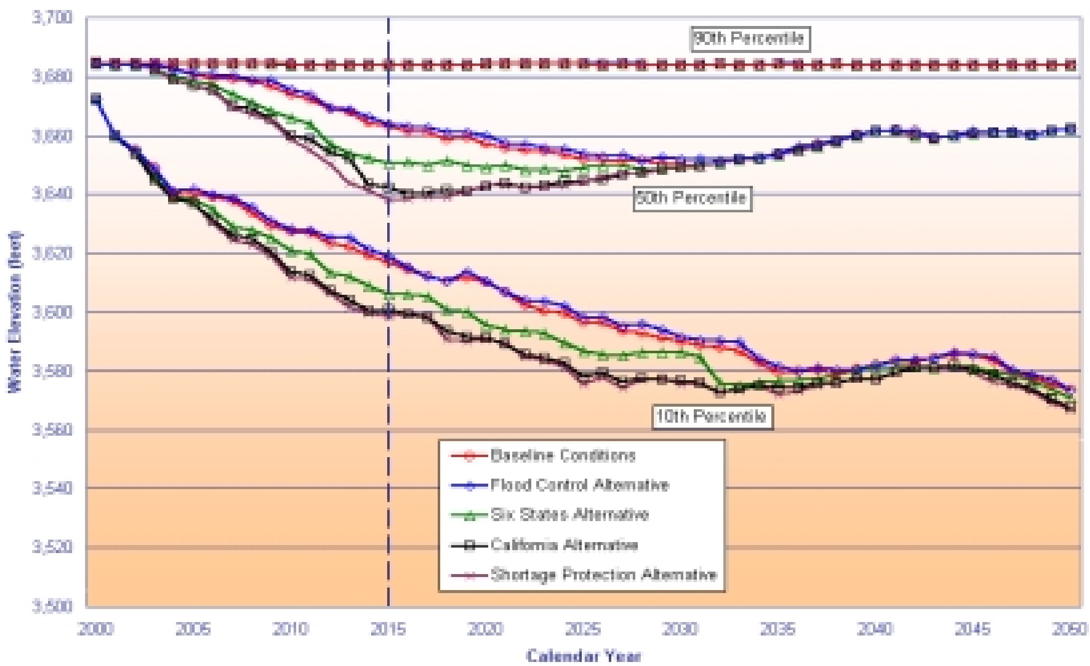


Figure 3.3-7 shows the frequency that Lake Powell water levels in future July months would exceed elevation 3695 feet msl under the baseline conditions and surplus alternatives. When the Lake Powell water level exceeds 3695 feet msl, the reservoir is considered to be essentially full. In year 2015, under baseline conditions, the percentage of values greater than or equal to elevation 3695 feet msl is 28 percent. In 2050, the percentage of values greater than or equal to elevation 3695 feet msl decreases to 26 percent.

Figure 3.3-7
Lake Powell Month of July Water Elevations
Comparison of Surplus Alternatives to Baseline Conditions
Percentage of Values Greater than or Equal to Elevation 3695 Feet

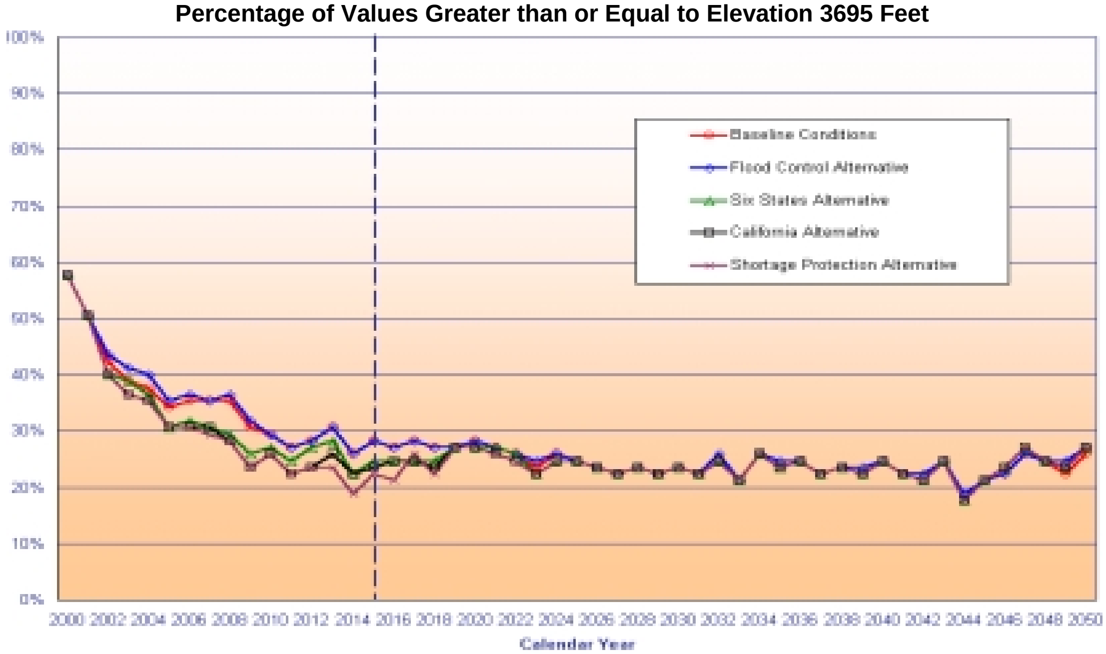


Figure 3.3-8 provides a comparison of the frequency that future Lake Powell water elevations under baseline conditions and the surplus alternatives would exceed a lake water elevation of 3590 feet msl. The lines represent the percentage of values greater than or equal to the lake water elevation of 3590 feet msl under the baseline conditions and surplus alternatives. In year 2015, under the baseline conditions, the percentage of values greater than or equal to elevation 3590 feet msl is 99 percent. In 2050, the percentage of values greater than or equal to elevation 3590 feet msl decreases to 86 percent for the baseline conditions.

3.3.4.2.4 Comparison of Surplus Alternatives to Baseline Conditions

Figure 3.3-6 compared the median and 10^{th} percentile water levels of the surplus alternatives to those of the baseline conditions. As discussed above, under baseline conditions, future Lake Powell water levels at the upper and lower 10^{th} percentiles would likely be temporary and the water level would fluctuate between them in response to multiyear variations in basin runoff conditions. The same would apply to all the surplus alternatives. Median (50^{th} percentile) and 10^{th} percentile values of the surplus alternatives are compared to those of the baseline conditions in Table 3.3-4. The values presented in this table include those for years 2015 and 2050 only.

Figure 3.3-8
Lake Powell End of Year Water Elevations
Comparison of Surplus Alternatives to Baseline Conditions
Percentage of Values Greater than or Equal to Elevation 3590 Feet

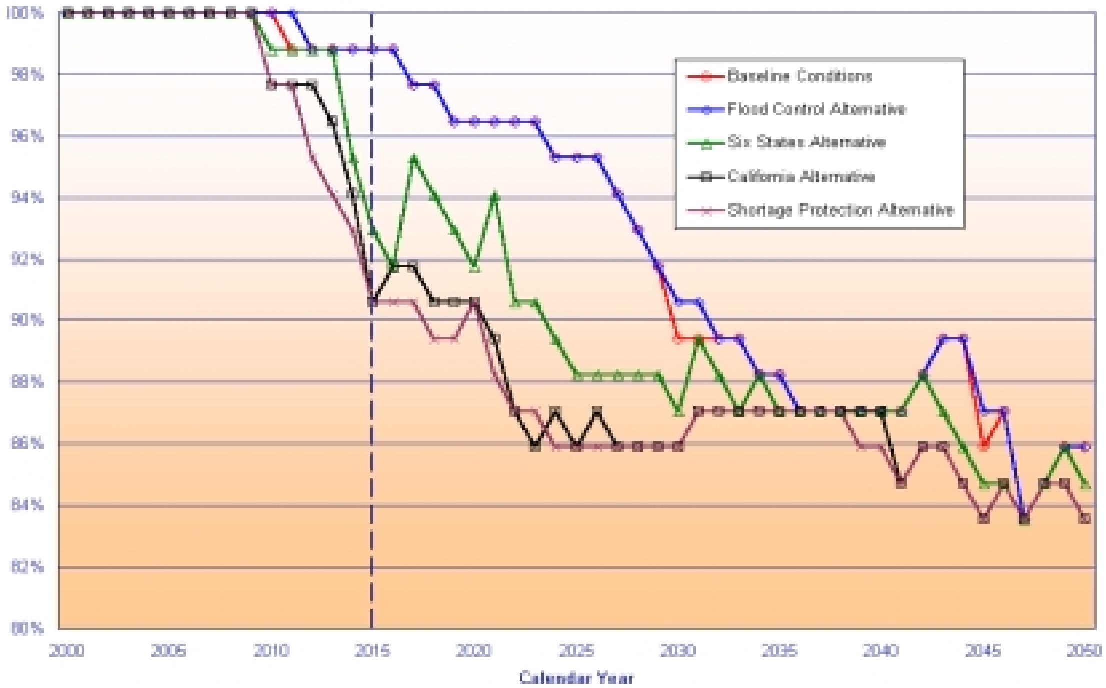


Table 3.3-4
Lake Powell End-of-Year Water Elevations
Comparison of Surplus Alternatives and Baseline Conditions
50th and 10th Percentile Values

Alternative	Year 2015		Year 2050	
	50th Percentile	10th Percentile	50th Percentile	10th Percentile
Baseline Conditions	3663	3617	3662	3573
Flood Control Alternative	3664	3618	3662	3573
Six States Alternative	3650	3606	3662	3570
California Alternative	3642	3600	3662	3567
Shortage Protection Alternative	3638	3598	3662	3567

Figure 3.3-7 compared the percentage of Lake Powell elevations that exceeded 3695 feet msl for the surplus alternatives and baseline conditions. Table 3.3-5 provides a summary of that comparison for years 2015 and 2050.

Table 3.3-5
Lake Powell End of July Water Elevations
Comparison of Surplus Alternatives and Baseline Conditions
Percentage of Values Greater than or Equal to Elevation 3695 Feet

Alternative	Year 2015	Year 2050
Baseline Conditions	28%	26%
Flood Control Alternative	28%	27%
Six States Alternative	25%	27%
California Alternative	24%	27%
Shortage Protection Alternative	22%	27%

Figure 3.3-8 compared the percentage of Lake Powell elevations that exceeded 3590 feet msl for the surplus alternatives and baseline conditions. Table 3.3-6 provides a summary of that comparison for years 2015 and 2050.

Table 3.3-6
Lake Powell End-of-Year Water Elevations
Comparison of Surplus Alternatives and Baseline Conditions
Percentage of Values Greater than or Equal to Elevation 3590 Feet

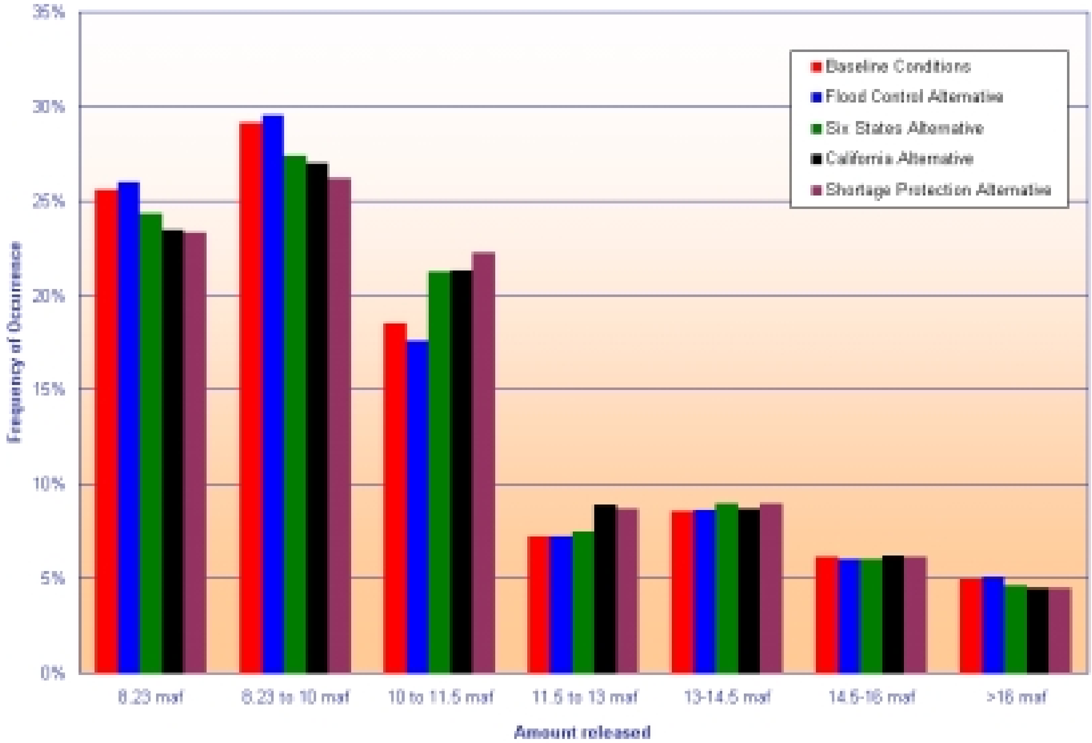
Alternative	Year 2015	Year 2050
Baseline Conditions	99%	86%
Flood Control Alternative	99%	86%
Six States Alternative	93%	85%
California Alternative	91%	84%
Shortage Protection Alternative	91%	84%

3.3.4.3 RIVER FLOWS BETWEEN LAKE POWELL AND LAKE MEAD

The river flows between Glen Canyon Dam and Lake Mead result from controlled releases from Glen Canyon Dam (Lake Powell) and include gains from tributaries in this reach of the river. Releases from Glen Canyon Dam are determined as previously discussed in Sections 3.2.1.2 and 3.3.1.1. The most significant gains from perennial streams include inflow from the Little Colorado River and Paria River. However, inflow from these streams is concentrated over very short periods of time, and on average, make up approximately 2 percent of the total annual flow in this reach of the river.

Figure 3.3-9 provides a comparison of the relative frequency of occurrence of annual releases from Lake Powell under the baseline conditions and surplus alternatives, during the interim surplus criteria period (through 2015). Releases between 8.23 and 11.5 maf generally correspond to years where equalization releases are being made from Lake Powell. The surplus water deliveries from Lake Mead associated with the interim surplus criteria tend to increase the relative frequency of equalization during that period compared to baseline conditions.

Figure 3.3-9
Histogram of Modeled Lake Powell Annual Releases (Water Years)
2001 to 2015 (85 Traces)



3.3.4.4 LAKE MEAD WATER LEVELS

This section provides a general description of Hoover Dam and Lake Mead, discusses historic Lake Mead water levels and summarizes the results of the future Lake Mead water level simulations under baseline conditions and the surplus alternatives.

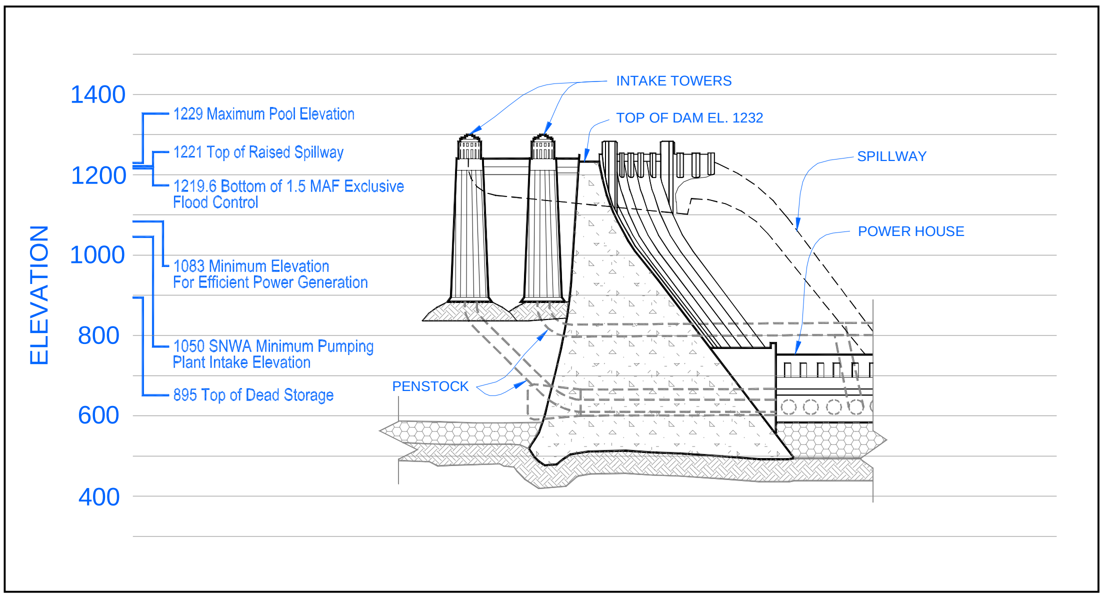
3.3.4.4.1 Dam and Reservoir Configuration

Hoover Dam and Lake Mead are operated with the following three main priorities: 1) river regulation, improvement of navigation, and flood control, 2) irrigation and domestic uses, including the satisfaction of present perfected water rights, and 3) power. The Boulder Canyon Project Act of 1928 specified flood control as the project purpose having first priority for operation of Hoover Dam and Lake Mead.

Hoover Dam is the northernmost Reclamation facility on the lower Colorado River and is located 326 miles downstream of Lee Ferry. Hoover Dam provides flood control protection and Lake Mead provides the majority of the storage capacity for the Lower Basin as well as significant recreation opportunities. Lake Mead storage capacity is 27.38 maf at a maximum water surface elevation of 1229.0 feet msl. At this elevation, Lake Mead's water surface area would equal 163,000 acres. The dam's four intake towers draw water from the reservoir at elevations above 895 feet to drive 17 generators within the dam's powerplant. The minimum water surface elevation for efficient power generation is 1083 feet msl.

Flood control regulations for Lake Mead were established to manage potential flood events arising from rain and snowmelt. Lake Mead's uppermost 1.5 maf of storage capacity, between elevations 1219.61 and 1229.0 feet, is allocated exclusively to flood control. Within this capacity allocation, 1.218 maf of flood storage is above elevation 1221.0 feet, the top of the raised spillway gates. Figure 3.3-10 illustrates some of the important Hoover Dam and Lake Mead water surface elevations that are referenced in subsequent sections.

Figure 3.3-10
Lake Mead and Hoover Dam Important Operating Elevations



Lake Mead usually is at its maximum water level in November and December. If required, system storage space-building is achieved between August 1 to January 1. Hoover Dam storage space-building releases are limited to 28,000 cfs, while the mean daily releases to meet the water delivery orders of Colorado River water entitlement holders normally range between 8,000 cfs to 18,000 cfs.

In addition to controlled releases from Lake Mead to meet water supply and power requirements, water is also diverted from Lake Mead at the Southern Nevada Water Authority's (SNWA) Saddle Island Intake Facilities, Boulder City's Hoover Dam