# Appendix A

## CRSS Model Documentation

This appendix describes the reservoir operating rules and related data used in Reclamation's Colorado River Simulation System (CRSS), as implemented in the RiverWare™ modeling system.

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# A.1 Background

Long-term policy and planning studies on the Colorado River have typically used computer modeling results from Bureau of Reclamation's (Reclamation) Colorado River Simulation System (CRSS). Developed in the 1980's as a Fortran-based modeling system, CRSS originally ran on a Cyber mainframe computer. CRSS modeled twelve major reservoirs and approximately 115 diversion points throughout the Colorado River Upper Basin and Lower Basin on a monthly time step. A major drawback of the Fortran-based CRSS was that the operating policies or rules were hardwired into the modeling code, making modification of those policies difficult.

Based on the need to initiate surplus and shortage studies for the Lower Basin in the early 1990s, Reclamation developed an annual time step model, CRSSez, implemented in Visual Basic (Bureau of Reclamation 1998). CRSSez primarily modeled the operation of Lake Powell and Lake Mead, representing the reservoirs upstream of Lake Powell as one aggregate reservoir, and the effect of reservoirs downstream of Lake Mead as part of the water demand from Lake Mead. CRSSez was used in the Interim Surplus Criteria Environmental Impact Statement (EIS) process to develop a model, and evaluate a range of alternatives.

In 1994, Reclamation began a collaborative research and development program with the University of Colorado and the Tennessee Valley Authority with the goal of developing a general-purpose modeling tool that could be used for both operations and planning on any river basin. This modeling tool, known as RiverWare™, is now being used by Reclamation's Upper and Lower Colorado Regions for both planning and operations (Fulp 1999). A major advantage of RiverWare™ is that the operational policies or rules are no longer hardwired into the modeling code (Zagona et al. 2001). The user expresses and prioritizes the rules through the RiverWare™ graphical user interface, and RiverWare™ then interprets the rules when a simulation is performed. Multiple rule sets can be used to perform different simulations using the same model and this provides the capability for efficient "what-if" analysis with respect to different policies.

Reclamation replaced the original CRSS model with a new model implemented in RiverWare™ in 1996. The new model has the same spatial and temporal resolution, uses the same basic input data (hydrology and consumptive use schedules), and uses the same physical process algorithms as the original CRSS. A rule set was also developed to mimic the policies contained in the original model. Comparison simulations were made between the original CRSS and the new model and rule set, with typical differences of less than 0.5 percent (Reclamation 1996).

Since 1996, enhancements to CRSS have consisted of developing new rule sets to reflect current operational policy as well as investigating and improving, where necessary, the physical process methodologies. A team of Reclamation engineers from the Upper and Lower Colorado Regions has been established for these purposes and continues to assess the need to further enhance CRSS to reflect new operational policies.

In 2005 a policy-screening model, CRSS-Lite was developed to replace CRSSez (Reclamation 2005). CRSS-Lite was developed in RiverWare™ and preserves the complexity and accuracy of CRSS with a significantly shorter model execution time, an advantage over CRSSez. CRSS-Lite was used extensively to evaluate and compare a multitude of operational strategies and alternatives in this EIS.

## A.2 Description of the Model

In summary, twelve Upper Basin and Lower Basin reservoirs are modeled: Fontenelle, Flaming Gorge, Starvation, Taylor Park, Blue Mesa, Morrow Point, Crystal, Navajo, Powell, Mead, Mohave, and Havasu in CRSS. Critical to this EIS was the allocation of shortages, which required breaking out several of the approximately 115 modeled diversions (demands and return flows) throughout the basin that had been aggregated in the original CRSS. The hydrologic "natural" inflows (flows corrected for upstream regulation and consumptive uses and losses) at 29 inflow points throughout the basin were also used from the standard CRSS hydrology data set covering the period 1906–2005.

## A.3 Initial Reservoir Conditions

The first year considered for the interim period of the proposed federal action is 2008. Since the initial modeling was performed in 2006, some projection of Colorado River system conditions was need. In order to establish the reservoir starting conditions for CRSS modeling, Reclamation’s 24-Month Study model is used to project the reservoir storage conditions as of end-of-calendar year 2007. This process inputs the storage conditions at the time the modeling is performed and adds to that several assumptions including estimates of snow pack and run-off for the intervening period (the period between when the model is run and December 31, 2007).

The hydrologic modeling that was performed and used in the analyses for the Draft EIS was undertaken in the fall of 2006 and used the August 2006 24-Month Study. For the Final EIS, more current estimates of inflow to Lake Powell in 2007 were available and these differed somewhat from the original assumptions that were used in the modeling for the Draft EIS. The lower inflow projections reflected the effects of the continued drought in the Colorado River Basin (which began in 2000). In order to provide the most current information available for the Final EIS, the alternatives were remodeled using the latest available inflow projections. Using this latest inflow forecast in the June 2007 24-Month Study provides different starting conditions for Lake Powell and Lake Mead from those used in the Draft EIS and shows that the projected Lake Powell and Lake Mead elevations for January 1, 2008 would be approximately 20 feet and one foot lower, respectively, than the starting elevations that were used in the Draft EIS.

Table A-1 provides the initial conditions for the Upper Basin and Lower Basin reservoirs that were used in the CRSS simulations for the Draft EIS and the Final EIS. Since the simulation begins in January 2008, these values reflect the end-of-calendar year 2007 reservoir elevations, as projected by the August 2006 24-Month Study and June 2007 24-Month Study, respectively.

Table A-1
Initial Reservoir Conditions
(End-of-Calendar Year 2007 Forecast)

| Reservoir | Draft EIS Initial Conditions[1] | | Final EIS Initial Conditions[2] | |
|---|---|---|---|---|
| | Elevation (feet msl) | Storage (af) | Elevation (feet msl) | Storage (af) |
| Fontenelle | 6,486.29 | 203,787 | 6,481.89 | 177,000 |
| Flaming Gorge | 6,029.67 | 3,336,300 | 6,023.89 | 3,119,000 |
| Starvation | 5,734.92 | 255,000 | 5,734.92 | 255,000 |
| Taylor Park | 9,308.32 | 67,260 | 9,306.45 | 64,000 |
| Blue Mesa | 7,489.99 | 581,270 | 7,490.00 | 581,000 |
| Morrow Point | 7,153.73 | 112,000 | 7,153.73 | 112,000 |
| Crystal | 6,753.04 | 16,970 | 6,753.04 | 17,000 |
| Navajo | 6,080.33 | 1,629,760 | 6,070.99 | 1,494,000 |
| Powell | 3,614.80 | 13,219,550 | 3,596.77 | 11,445,000 |
| Mead | 1,116.53 | 13,023,940 | 1,114.85 | 12,864,000 |
| Mohave | 638.71 | 1,582,960 | 638.71 | 1,583,000 |
| Havasu | 445.80 | 539,520 | 445.80 | 539,000 |
| Total Storage Volume | NA | 34,568,317 | NA | 32,250,000 |

*1 Projected initial conditions based on August 2006 24-Month Study.*
*2 Projected initial conditions based on June 2007 24-Month Study.*
*msl: mean sea level*
*af: acre-foot*

## A.4 Reservoirs Upstream of Lake Powell

The reservoirs upstream of Lake Powell are operated to meet monthly storage targets (or “rule curves”) and downstream demands. The basic procedure is that given the inflow for the current month, the release will be either the release necessary to meet the target storage, or the release necessary to meet demands downstream of the reservoir, whichever is greater. The rule curves are input for each reservoir, but are modified during the simulation for Flaming Gorge, Blue Mesa, and Navajo to simulate operations based on the imperfect inflow forecasts that are encountered in actual reservoir operations. Furthermore, each reservoir is constrained to operate within user-supplied minimum and maximum releases (mean monthly release in cubic feet per second [cfs]) as specified in Table A-2.

Table A-2
Release Constraints for Reservoirs Upstream of Lake Powell

| Reservoir | Minimum Release (cfs) | Maximum Release (cfs) |
|---|---|---|
| Fontenelle | 500 | 18,700 |
| Flaming Gorge | 800 | 4,900 |
| Starvation | 100 | 5,000 |
| Taylor Park | 50 | 5,000 |
| Blue Mesa | 270 | 5,000 |
| Morrow Point | 300 | 5,000 |
| Crystal | 300 | 4,200 |
| Navajo | 300 | 5,900 |

For Flaming Gorge, Blue Mesa, and Navajo, the target storage is computed by using an inflow forecast for the period January through July, again to mimic the imperfect forecasts seen in actual operations. The inflow forecast (for the current month through July) is computed as a weighted average of the long-term average natural inflow and the natural inflow assumed for the year being modeled. The weights used are listed in Table A-3.

Table A-3
Weights for Inflow Forecast for Reservoirs Upstream of Lake Powell

| Month | Natural Inflow Weight | Average Natural Inflow Weight |
|---|---|---|
| January | 0.3 | 0.7 |
| February | 0.4 | 0.6 |
| March | 0.5 | 0.5 |
| April | 0.7 | 0.3 |
| May | 0.7 | 0.3 |
| June | 0.7 | 0.3 |
| July | 0.6 | 0.4 |

The long-term, average natural inflows into the Flaming Gorge, Blue Mesa and Navajo reservoirs are listed in Table A-4 (in thousand acre-feet [kaf]).

Table A-4
Average Natural Inflows for Reservoirs Upstream of Lake Powell (kaf)

| Reservoir | Jan | Feb | Mar | Apr | May | Jun | Jul |
|---|---|---|---|---|---|---|---|
| Flaming Gorge | 23.3 | 20.9 | 33.8 | 87.9 | 250.4 | 327.8 | 157.5 |
| Blue Mesa | 34.0 | 39.5 | 94.6 | 176.0 | 339.8 | 561.6 | 346.8 |
| Navajo | 18.8 | 24.6 | 69.3 | 176.9 | 297.3 | 284.7 | 120.1 |

Based on the inflow forecast, the rule computes the volume necessary to release from the current month through July, assuming the reservoir will fill in July:

> Release needed for the current month = (current contents - live capacity + predicted remaining inflow) divided by the number of months remaining until the end of July

The target storage for the current month is then computed, adjusting the storage at the end of the previous month for any gains or losses upstream of the reservoir:

> Target storage = previous storage - release needed + gains – losses

# A.5 Lake Powell Operation

The operation of Lake Powell depends on a rule curve consisting of a forecast-driven operation from January through July that attempts to fill the reservoir to July target storage, and an operation from August through December that attempts to draw down the reservoir to December target storage. The July and December targets are 23.822 million acre-feet (maf) (500,000 af of space) and 21.900 maf (2.422 kaf of space), respectively. Another rule simulates the occurrence of Beach/Habitat-Building Flows (BHBFs or spike flows). Two other higher priority rules ensure that the minimum objective release of 8.23 million acre-feet per year (mafy) is met and that equalization of Lake Powell and Lake Mead is accomplished when necessary. Release constraints that reflect the 1996 Record of Decision on the Operation of Glen Canyon Dam are also part of the Lake Powell rule set.

Sections A.5.1 through A.5.6 that follow describe modeling assumptions for Lake Powell operation that are common to all six alternatives. A summary comparison of the Lake Powell operational strategy for each alternative is provided in Attachment A to this Appendix (Table Att. A-1).

## A.5.1 Lake Powell Inflow Forecast

The unregulated Lake Powell inflow forecast from the current month through July is computed as

> unregulated Lake Powell inflow = natural flow into Lake Powell - estimated Upper Basin depletions + the forecast error
>
> where: the forecast error is computed using equations derived from an analysis of past Colorado River forecasts and runoff data for the period 1947 to 1983.

An analysis of these data reveals two strongly established patterns: (1) high runoff years are under-forecast, and low runoff years are over-forecast; and (2) the error in the current month's seasonal forecast is strongly correlated with the error in the preceding month's forecast (Reclamation 1985). A regression model was developed to aid in determining the error to be incorporated into the seasonal forecast for each month from January to June. The error is the sum of a deterministic component and a random component. The deterministic component is computed from the regression equation. The random component is computed by multiplying the standard error of the regression equation by a random mean deviation selected from a standard normal distribution.

The forecast error equation has the following form (all runoff units are maf):

$$E_i = a_i X_i + b_i E_{(i-1)} + c_i + Z_r d_i$$

where:

- $i$ = month,
- $E_i$ = error in the forecast for month "i,"
- $X_i$ = natural runoff into Lake Powell from month "i" through July,
- $a_i$ = linear regression coefficient for Xi,
- $E_{(i-1)}$ = previous month's forecast error,
- $b_i$ = linear regression coefficient for E(i-1),
- $c_i$ = constant term in regression equation for month "i,"
- $Z_r$ = randomly determined deviation, and
- $d_i$ = standard error of estimate for regression equation for month "i."

Table A-5 summarizes the regression equation coefficients for each month.

Table A-5
Lake Powell Inflow Forecast Regression Equation Coefficients

| Month | $a_i$ | $b_i$ | $c_i$ | $d_i$ |
|---|---|---|---|---|
| January | 0.70 | 0.00 | -8.195 | 1.270 |
| February | 0.00 | 0.80 | -0.278 | 0.977 |
| March | 0.00 | 0.90 | 0.237 | 0.794 |
| April | 0.00 | 0.76 | 0.027 | 0.631 |
| May | 0.00 | 0.85 | 0.132 | 0.377 |
| June | 0.24 | 0.79 | 0.150 | 0.460 |

The magnitude of the June forecast error is constrained to not exceed 50 percent of the May forecast error and the July forecast error is equal to 25 percent of the June forecast error.

### A.5.2 January through July Operation

To accomplish the operation from January through July, the unregulated forecast is first adjusted to account for potential reservoir regulation upstream of Lake Powell. This potential regulation is currently computed as just the sum of the available space (live capacity – previous month’s storage) in Fontenelle, Flaming Gorge, Blue Mesa, and Navajo reservoirs. Using the regulated forecast inflow, the total volume of water necessary to release from the current month through July is computed as

total volume to release = end of previous month’s storage – July target storage + forecast regulated inflow – loss due to evaporation – loss due to bank storage

The release for the current month is then computed by multiplying the total volume to release by a fraction for the current month, where the fraction reflects a user-supplied preferred weighting pattern. The weights and resulting fractions used for this study are listed in Table A-6.

Table A-6
Lake Powell January through July Operation Weights and Resulting Fractions

| Month | Weights | Fractions |
|---|---|---|
| January | 0.170 | 0.170 |
| February | 0.160 | 0.193 |
| March | 0.130 | 0.194 |
| April | 0.100 | 0.185 |
| May | 0.100 | 0.227 |
| June | 0.160 | 0.471 |
| July | 0.180 | 1.000 |

The fraction is computed as current month's weight divided by the sum of the current and remaining month's weights for the season.

During the operation from January through July, the computed release is constrained to be at least as great as the total volume divided by the number of months remaining. This constraint ensures that sufficient water is released early during high forecast years. Lake Powell’s operational release during January through July is further constrained in each month to be within a minimum and maximum range (currently set to 6,500 and 25,000 cfs, respectively).

An additional constraint is placed on computed monthly release during spill avoidance. If the calculated average flow for a given month is in excess of 1.0 maf, then it is held to a maximum of 1.0 maf each month.

### A.5.3 August through December Operation

Conceptually, the computation for the operation from August through December is identical to the computation made for the operation from January through July. The regulated inflow forecast is simply the natural inflow, adjusted for Upper Basin depletions, and potential reservoir regulation with no forecast error added. The potential reservoir regulation is again computed as the sum of the available space in Fontenelle, Flaming Gorge, Blue Mesa, and Navajo reservoirs, where the space is the target storage in December for each reservoir minus the end of the previous month’s storage. User-supplied weights are also used to compute the current month release from the total volume to release. The weights and resulting fractions are listed in Table A-7.

Table A-7
Lake Powell August through December Operation Weights and Resulting Fractions

| Month | Weights | Fractions |
|---|---|---|
| August | 0.266 | 0.266 |
| September | 0.200 | 0.272 |
| October | 0.156 | 0.292 |
| November | 0.156 | 0.413 |
| December | 0.222 | 1.000 |

Two additional constraints are placed on the computed monthly release to ensure a smooth operation. In July, the release is constrained to be at least 1.0 maf if Lake Powell's storage is greater than 23.0 maf. From July through December, the release is constrained to not exceed 1.5 maf, as long as a 1.5 maf release results in storage at Lake Powell less than 23.822 maf. Lake Powell's operational release during August through December is further constrained in each month to be within a minimum and maximum range (currently set to 6,500 and 25,000 cfs, respectively).

### A.5.4 602(a) Storage Requirement

The 602(a) storage requirement refers to the quantity of water required to be in storage in the Upper Basin so as to assure future deliveries to the Lower Basin without impairing annual consumptive uses in the Upper Basin (Bureau of Reclamation 1985). The current implementation of that storage requirement duplicates the original CRSS calculation. It computes a storage amount necessary in the Upper Basin to meet the minimum objective release and Upper Basin depletions over the next "n" years, assuming the inflow over that period would follow that seen in the most "critical period on record." The critical period in the Colorado River basin occurred in 1953 through 1964, a length of 12 years. Inflows from these years are used in the calculation of 602(a) storage.

At the beginning of each calendar year, a value for 602(a) storage is computed by the following formula:

602a = {(UBDepletion + UBEvap)* (1 – percentShort/ 100) + minObjRel – criticalPeriodInflow} * 12 + minPowerPoolStorage

where:

| | | |
|---|---|---|
| 602a | = | the 602(a) storage requirement |
| UBDepletion | = | the average over the next 12 years of the Upper Basin scheduled depletions |
| UBEvap | = | the average annual evaporation loss in the Upper Basin (currently set to 560 kaf) |
| percentShort | = | the percent shortage that will be applied to Upper Basin depletions during the critical period (currently set to zero) |
| minObjRel | = | the minimum objective release to the Lower Basin (currently set to 8.23 maf) |
| criticalPeriodInflow | = | average annual natural inflow into the Upper Basin during the critical period (1953–1964) (currently set to 12.18 maf) |
| minPowerPoolStorage | = | the amount of minimum power pool to be preserved in Upper Basin reservoirs (currently set to 5.179 maf) |

All parameter values currently used were as found in the original CRSS data files converted from the Cyber mainframe in 1994.

Additionally, since 2004, the Interim 602(a) Storage Guideline (69 Fed. Reg. 28945) has been included in CRSS. This guideline necessitates that for the 602(a) storage requirement to be met, Lake Powell storage must be greater than 14.85 maf (elevation 3,630 feet msl) on September 30. This interim guideline provides guidance to the Secretary in making a determination of the quantity of water considered necessary as of September 30 of each year to assist in implementation of and as required by Article II(1) of the 1970 Criteria for Coordinated Long-Range Operation of Colorado River Reservoirs (Long-Range Operating Criteria or LROC) pursuant to the Colorado River Basin Project Act of September 30, 1968. The interim guideline specifies that:

1. through the year 2016, 602(a) storage requirements determined in accordance with Article II(1) of the LROC shall utilize a value of not less than 14.85 maf (elevation 3,630 feet msl) for Lake Powell. Accordingly, when projected September 30 Lake Powell storage is less than 14.85 maf (elevation 3,630 feet msl), the objective will be to maintain a minimum annual release of water from Lake Powell of 8.23 maf, consistent with Article II(2) of the LROC;

2. under the current area-capacity relationship at Lake Powell, a reservoir elevation of 3,630 feet msl corresponds to 14.85 maf of storage. In the event that a sediment survey is performed at Lake Powell and a revised area-capacity relationship is determined before 2016, the revised water storage volume that correlates with the

reservoir elevation of 3,630 feet msl at Lake Powell shall be used in Section V(1) of this Interim 602(a) Storage Guideline; and

3. the Interim 602(a) Storage Guideline shall be utilized in the operation of the Colorado River from 2005 through 2016. This guideline will first be implemented in the development of the 2005 Colorado River Annual Operating Plan (AOP) and for all subsequent AOPs through 2016.

In the modeling for the Final EIS, the Interim 602(a) Storage Guideline is in effect through 2016. In the CRSS simulation, following the 602(a) storage computation described above, a subsequent rule checks to see if Lake Powell elevation is above 3,630 feet msl on September 30. The 602(a) requirement is not met if projected September 30 elevation of Lake Powell is below 3,630 feet msl, through 2016.

### A.5.5 Predicting End-of-Water Year Volumes of Lake Powell and Lake Mead

Lake Powell end-of-water year (EOWY) volume is predicted each month by taking the end of the previous month's storage, adding the estimated inflow, subtracting the estimated release, and subtracting the estimate of evaporation and change in bank storage. All estimated values are for the period from the current month through September. The estimated inflow is just the regulated inflow forecast previously discussed, where the forecast error is included through July. The estimated release is based on the operation from January through July and the operation for August and September. The estimated evaporation and bank storage losses are based on an initial estimate of the EOWY volume.

Similarly, the Lake Mead EOWY volume is predicted each month by taking the end of previous month's volume, adding the estimated Lake Powell release, subtracting the estimated Lake Mead release, adding the average gain between Lake Powell and Lake Mead, subtracting the Southern Nevada depletion, and subtracting the estimate of evaporation and change in bank storage. Again, all values are for the period from the current month through September. Lake Mead's release is estimated as the sum of the depletions downstream of Lake Mead and the reservoir regulation requirements (including evaporation losses) for Lake Mohave and Lake Havasu minus the gains below Lake Mead.

The changes in volume of water storage in Lake Powell and Lake Mead are calculated by the model using relationship curves that are programmed into the model. These relationship curves correlate the water surface elevation to live capacity, total capacity, and surface area for each respective reservoir. Tables which present the corresponding values for the range of operational elevations at Lake Powell and Lake Mead are provided in Attachment B to this appendix (Table Att. B-1 and Table Att. B-2, respectively).

### A.5.6 Beach/Habitat-Building Flows

Under the current rule that implements BHBFs, a BHBF is triggered for the current month if the following conditions are met:

- in January, if the unregulated inflow forecast for January through July (the natural flow – Upper Basin depletions plus forecast error) is greater than the “January trigger volume” (currently set to 13.0 maf); and

- in January through July, if the current month’s Lake Powell release is greater than the “release trigger” (currently set to 1.5 maf) or if the release volume for the current month through July equally distributed over those months would result in a release greater than the release trigger.

Once a BHBF has been triggered, if Lake Powell would have had to spill in that month anyway, the total outflow from Lake Powell is not increased; rather the volume for the BHBF (currently set to 200 kaf) is taken from the total outflow already determined by the operational rule. If Lake Powell was not going to spill in that month, then the total outflow from Lake Powell is increased (i.e., the volume for the BHBF is taken from Lake Powell’s storage). Under the case where the BHBF is triggered even though the current month’s release is less than the release trigger, the rule re-sets Lake Powell’s outflow for that month to the trigger release amount (1.5 maf).

Under all circumstances, only one BHBF is made per calendar year in the model.

## A.5.7 Minimum Objective Release

A minimum objective release is required from Lake Powell only under the No Action Alternative, as discussed below. The minimum release required under the action alternatives varies by alternative and Lake Powell volume. These releases are described in Section A.5.9.

### *A.5.7.1 No Action Alternative*

Under the No Action Alternative, a higher priority rule ensures that the previously described Lake Powell operation will satisfy a minimum objective release to the Lower Basin, currently equal to 8.23 maf over each water year (October through September). Similar to the weighting and release fraction scheme used for the operational rule, a preferred release pattern for each month to meet the minimum objective release is supplied and a fraction is computed. The release pattern (in kaf) and resulting fractions are listed in Table A-8.

Table A-8
Lake Powell Release Pattern and Resulting Fractions
No Action Alternative

| Month | 8,230 kaf | |
|---|---|---|
| | Release (kaf) | Fraction |
| October | 600 | 0.073 |
| November | 600 | 0.079 |
| December | 800 | 0.114 |
| January | 800 | 0.128 |
| February | 600 | 0.110 |
| March | 600 | 0.124 |
| April | 600 | 0.142 |
| May | 600 | 0.165 |
| June | 650 | 0.215 |
| July | 850 | 0.357 |
| August | 900 | 0.588 |
| September | 630 | 1.000 |
| Total | 8,230 | ----- |

The fraction is computed as current month's release divided by the sum of the current and remaining months' releases through September.

Each month the rule computes the volume of water remaining to meet the minimum objective release for the current water year (accounting for the water released previously in the water year) and multiplies that volume by the release fraction. The release determined by the operational rule must then be at least as great as this resulting minimum objective release for the month.

## A.5.8 Equalization of Lake Powell and Lake Mead

### *A.5.8.1 No Action Alternative*

Under the No Action Alternative, the equalization of storage between Lake Powell and Lake Mead is implemented in a rule that accurately models the past and current operations of equalization at Glen Canyon Dam. The rule first determines if equalization needs to occur, and if so, determines how much water to release from Lake Powell to accomplish it. The rule is in effect from January through September of each year. The rule states that equalization needs to occur if two criteria are met: (1) if the storage in the Upper Basin meets the 602(a) storage requirement; and (2) if the projected EOWY storage in Lake Powell is greater than that in Lake Mead.

The storage in the Upper Basin is computed for each month (January through September) and consists of the predicted EOWY storage in Lake Powell, plus the sum of the end of previous month's storage for Flaming Gorge, Blue Mesa, and Navajo reservoirs. That storage is then compared to the computed value of 602(a) storage, described above, to determine if the 602(a) storage requirement is met each month. The method of estimating the EOWY storage is described above.

The release for equalization is computed by taking half of the difference between the predicted EOWY volumes of Lake Powell and Lake Mead and dividing by the number of months remaining through September. Evaporation and bank storage losses at Lake Powell and Lake Mead are included in the calculation, resulting in an iterative procedure to arrive at the computed equalization release. The iteration stops when the forecast EOWY volumes of Lake Powell and Lake Mead are within a user-specified tolerance. That tolerance is currently set to 250,000 af.

The computed equalization release for each month is constrained in three ways: (1) if the additional release due to equalization would cause the total Upper Basin storage to drop below the 602(a) storage requirement, then the amount of the equalization release can be adjusted downward but cannot be reduced below 8.23 maf; (2) the equalization release is reduced if it would cause Lake Mead volumes to exceed its exclusive flood control space; and (3) the equalization release is constrained to be not greater than 25,000 cfs, the maximum normal release as per the Glen Canyon Operating Criteria.

#### *A.5.8.2 Basin States Alternative*

Under the Basin States Alternative, the equalization of storage between Lake Powell and Lake Mead is implemented in a rule that first determines if equalization needs to occur, and if so, then determines how much water to release from Lake Powell to accomplish it. The rule is in effect from January through September of each year. The rule states that equalization needs to occur if two criteria are met: (1) if the EOWY elevation of Lake Powell is predicted to be equal to or higher than the Equalization Level (see Table A-9); and (2) if the EOWY storage in Lake Powell is greater than EOWY storage in Lake Mead. The Basin States Alternative substitutes the 602(a) Storage and Interim 602(a) Storage Guideline with the Equalization Level for each year 2008 through 2026.

In years when Lake Powell EOWY elevation is projected to be equal to or above the Equalization Level and the EOWY volume of Lake Powell is projected to be above the EOWY volume of Lake Mead, a volume of water greater than 8.23 maf is scheduled for annual release from Lake Powell to the extent necessary to equalize storage in the two reservoirs. Otherwise, if Lake Powell EOWY volume is not higher than Lake Mead EOWY volume, the annual release volume from Lake Powell is scheduled at 8.23 maf.

The release for equalization is computed by taking half of the difference between the predicted EOWY volumes of Lake Powell and Lake Mead and dividing by the number of months remaining through September. Evaporation and bank storage losses at Lake Powell and Lake Mead are included in the calculation, resulting in an iterative procedure to arrive at the computed equalization release. The iteration stops when the forecast EOWY volumes of Lake Powell and Lake Mead are within a user-specified tolerance. That tolerance is currently set to 250,000 af.

Table A-9
Lake Powell Equalization Elevation
Basin States Alternative

| Year | Equalization Elevation (feet msl) |
|---|---|
| 2008 | 3,636 |
| 2009 | 3,639 |
| 2010 | 3,642 |
| 2011 | 3,643 |
| 2012 | 3,645 |
| 2013 | 3,646 |
| 2014 | 3,648 |
| 2015 | 3,649 |
| 2016 | 3,651 |
| 2017 | 3,652 |
| 2018 | 3,654 |
| 2019 | 3,655 |
| 2020 | 3,657 |
| 2021 | 3,659 |
| 2022 | 3,660 |
| 2023 | 3,662 |
| 2024 | 3,663 |
| 2025 | 3,664 |
| 2026 | 3,666 |

The computed equalization release for each month is constrained in three ways: (1) if the additional release due to equalization would cause the Lake Powell EOWY elevation to drop below the Equalization Line, then the amount of the equalization release is reduced to prevent this from happening; (2) the equalization release is reduced if it would cause Lake Mead volumes to exceed its exclusive flood control space; and (3) the equalization release is constrained to be not greater than 25,000 cfs, the maximum normal release as per the Glen Canyon Operating Criteria.

#### *A.5.8.3 Conservation Before Shortage Alternative*

The equalization method for Lake Powell under the Conservation Before Shortage Alternative is identical to that of the Basin States Alternative.

#### *A.5.8.4 Water Supply Alternative*

The equalization criteria for Lake Powell under the Water Supply Alternative are identical to those of the No Action Alternative.

#### *A.5.8.5 Reservoir Storage Alternative*

The equalization criteria for Lake Powell under the Reservoir Storage Alternative are identical to those of the No Action Alternative.

#### *A.5.8.6 Preferred Alternative*
The equalization method for Lake Powell under the Preferred Alternative is identical to that of the Basin States and Conservation Before Shortage Alternatives.

### A.5.9 Water Year Releases When Equalization Does Not Apply

#### *A.5.9.1 No Action Alternative*
Under the No Action Alternative, Lake Powell water releases are constrained by the minimum objective release as described in Section A.5.7.

#### *A.5.9.2 Basin States Alternative*
Under the Basin States Alternative, when the EOWY level of Lake Powell is below the Equalization Level (see Table A-9), a higher priority rule ensures that the Lake Powell operation will satisfy a water year release to the Lower Basin, between 7.00 maf and 9.50 maf, depending on elevations in Lake Powell and Lake Mead. Similar to the weighting and release fraction scheme used for the operational rule in the No Action Alternative, a preferred release pattern for each month to meet the water year release is supplied and a fraction is computed. The fraction is computed as current month's release divided by the sum of the current and remaining months' releases through September. Each month the rule computes the volume of water remaining to meet the release for the current water year (accounting for the water released previously in the water year) and multiplies that volume by the release fraction. The release determined by the operational rule must then be at least as great as this resulting release for the month.

Specific release patterns (in kaf) and resulting fractions for the Basin States Alternative are provided in Table A-10.

Table A-10
Lake Powell Release Patterns and Resulting Fractions
Basin States Alternative

| Total Release | 7,000 kaf | | 7,480 kaf | | 8,230 kaf | | 9,000 kaf | | 9,500 kaf | |
|---|---|---|---|---|---|---|---|---|---|---|
| Month | Release (kaf) | Fraction | Release (kaf) | Fraction | Release (kaf) | Fraction | Release (kaf) | Fraction | Release (kaf) | Fraction |
| October | 480 | 0.069 | 480 | 0.064 | 600 | 0.073 | 600 | 0.067 | 600 | 0.063 |
| November | 500 | 0.077 | 500 | 0.071 | 600 | 0.079 | 600 | 0.071 | 600 | 0.067 |
| December | 600 | 0.100 | 600 | 0.092 | 800 | 0.114 | 800 | 0.103 | 800 | 0.096 |
| January | 600 | 0.111 | 800 | 0.136 | 800 | 0.128 | 800 | 0.114 | 850 | 0.113 |
| February | 600 | 0.124 | 600 | 0.118 | 600 | 0.110 | 650 | 0.105 | 650 | 0.098 |
| March | 500 | 0.118 | 600 | 0.133 | 600 | 0.124 | 650 | 0.117 | 650 | 0.108 |
| April | 500 | 0.134 | 500 | 0.128 | 600 | 0.142 | 600 | 0.122 | 650 | 0.121 |
| May | 500 | 0.155 | 600 | 0.176 | 600 | 0.165 | 650 | 0.151 | 800 | 0.170 |
| June | 600 | 0.221 | 600 | 0.214 | 650 | 0.215 | 800 | 0.219 | 900 | 0.231 |
| July | 800 | 0.377 | 800 | 0.364 | 850 | 0.357 | 1,000 | 0.351 | 1,050 | 0.350 |
| August | 800 | 0.606 | 800 | 0.571 | 900 | 0.588 | 1,050 | 0.568 | 1,100 | 0.564 |
| September | 520 | 1.000 | 600 | 1.000 | 630 | 1.000 | 800 | 1.000 | 850 | 1.000 |
| Total | 7,000 | ----- | 7,480 | ----- | 8,230 | ----- | 9,000 | ----- | 9,500 | ----- |

In years when Lake Powell EOWY elevation is projected to be lower than the Equalization Level and equal to or above 3,575 feet msl, and the projected Lake Mead EOWY elevation is equal to or above 1,075 feet msl, then the annual release volume is scheduled to be 8.23 maf. If the projected Lake Mead EOWY elevation is below 1,075 feet msl, however, then a volume of water is scheduled for annual release from Lake Powell to the extent necessary to balance storage in the two reservoirs, constrained by being no more than 9.00 maf and no less than 7.00 maf.

In years when Lake Powell EOWY elevation is projected to be lower than 3,575 feet msl and at or above 3,525 feet msl, and the projected Lake Mead EOWY elevation is equal to or above 1,025 feet msl, then the annual release volume is scheduled at 7.48 maf. However, if Lake Powell EOWY elevation is projected to be lower than 3,575 feet msl and at or above 3,525 feet msl, but the projected Lake Mead EOWY elevation is below 1,025 feet msl, then the annual release volume is scheduled at 8.23 maf.

In years when Lake Powell EOWY elevation is projected to be below 3,525 feet msl, then a volume of water is scheduled for annual release from Lake Powell to the extent necessary to balance storage in the two reservoirs, constrained by being no more than 9.50 maf and no less than 7.00 maf.

### *A.5.9.3 Conservation Before Shortage Alternative*

Water year releases for Lake Powell under the Conservation Before Shortage Alternative are identical to those of the Basin States Alternative.

### *A.5.9.4 Water Supply Alternative*

Under the Water Supply Alternative, when projected EOWY storage in the Upper Basin is less than the 602(a) storage requirement, a higher priority rule ensures that the Lake Powell operation will satisfy a water year release to the Lower Basin between 7.00 maf and 9.50 maf, depending on projected EOWY elevations in Lake Powell and Lake Mead. Similar to the weighting and release fraction scheme used for the operational rule, a preferred release pattern for each month to meet the water year release is supplied and a fraction is computed. The fraction is computed as current month's release divided by the sum of the current and remaining months' releases through September. Each month the rule computes the volume of water remaining to meet the release for the current water year (accounting for the water released previously in the water year) and multiplies that volume by the release fraction. The release determined by the operational rule must then be at least as great as this resulting release for the month.

Specific release patterns (in kaf) and resulting fractions for the Water Supply Alternative are provided in Table A-11.

In years when the Lake Powell EOWY volume is projected to be below the 602(a) storage requirement and equal to or above 3,575 feet msl, and the projected Lake Mead EOWY elevation is equal to or above 1,075 feet msl, then the annual release volume is scheduled to be 8.23 maf. If the projected Lake Mead EOWY elevation is below 1,075 feet msl, however, then a volume of water is scheduled for annual release from Lake Powell to the extent necessary to balance storage in the two reservoirs, constrained by being no more than 9.50 maf and no less than 7.00 maf.

In years when the Lake Powell EOWY elevation is projected to be less than 3,575 feet msl, then a volume of water is scheduled for annual release from Lake Powell to the extent necessary to balance storage in the two reservoirs, constrained by being no more than 9.50 maf and no less than 7.00 maf.

Table A-11
Lake Powell Release Patterns and Resulting Fractions
Water Supply Alternative

| Total Release | 7,000 kaf | | 8,230 kaf | | 9,500 kaf | |
|---|---|---|---|---|---|---|
| Month | Release (kaf) | Fraction | Release (kaf) | Fraction | Release (kaf) | Fraction |
| October | 480 | 0.069 | 600 | 0.073 | 600 | 0.063 |
| November | 500 | 0.077 | 600 | 0.079 | 600 | 0.067 |
| December | 600 | 0.100 | 800 | 0.114 | 800 | 0.096 |
| January | 600 | 0.111 | 800 | 0.128 | 850 | 0.113 |
| February | 600 | 0.124 | 600 | 0.110 | 650 | 0.098 |
| March | 500 | 0.118 | 600 | 0.124 | 650 | 0.108 |
| April | 500 | 0.134 | 600 | 0.142 | 650 | 0.121 |
| May | 500 | 0.155 | 600 | 0.165 | 800 | 0.170 |
| June | 600 | 0.221 | 650 | 0.215 | 900 | 0.231 |
| July | 800 | 0.377 | 850 | 0.357 | 1,050 | 0.350 |
| August | 800 | 0.606 | 900 | 0.588 | 1,100 | 0.564 |
| September | 520 | 1.000 | 630 | 1.000 | 850 | 1.000 |
| Total | 7,000 | ----- | 8,230 | ----- | 9,500 | ----- |

### *A.5.9.5 Reservoir Storage Alternative*

Under the Reservoir Storage Alternative, when projected EOWY storage in the Upper Basin is less than the 602(a) storage requirement, a higher priority rule ensures that the Lake Powell operation will satisfy a water year release to the Lower Basin between 7.80 maf and 9.50 maf, depending on projected EOWY elevations in Lake Powell and Lake Mead. Similar to the weighting and release fraction scheme used for the operational rule, a preferred release pattern for each month to meet the water year release is supplied and a fraction is computed. The fraction is computed as current month's release divided by the sum of the current and remaining months' releases through September. Each month the rule computes the volume of water remaining to meet the release for the current water year (accounting for the water released previously in the water year) and multiplies that volume by the release fraction. The release determined by the operational rule must then be at least as great as this resulting release for the month.

Specific release patterns (in kaf) and resulting fractions for the Reservoir Storage Alternative are provided in Table A-12.

Table A-12
Lake Powell Release Patterns and Resulting Fractions
Reservoir Storage Alternative

| Total Release | 7,800 kaf | | 8,230 kaf | | 9,500 kaf | |
|---|---|---|---|---|---|---|
| Month | Release (kaf) | Fraction | Release (kaf) | Fraction | Release (kaf) | Fraction |
| October | 600 | 0.077 | 600 | 0.073 | 600 | 0.063 |
| November | 600 | 0.083 | 600 | 0.079 | 600 | 0.067 |
| December | 600 | 0.091 | 800 | 0.114 | 800 | 0.096 |
| January | 800 | 0.133 | 800 | 0.128 | 850 | 0.113 |
| February | 600 | 0.115 | 600 | 0.110 | 650 | 0.098 |
| March | 600 | 0.130 | 600 | 0.124 | 650 | 0.108 |
| April | 600 | 0.150 | 600 | 0.142 | 650 | 0.121 |
| May | 600 | 0.176 | 600 | 0.165 | 800 | 0.170 |
| June | 600 | 0.214 | 650 | 0.215 | 900 | 0.231 |
| July | 800 | 0.364 | 850 | 0.357 | 1,050 | 0.350 |
| August | 800 | 0.571 | 900 | 0.588 | 1,100 | 0.564 |
| September | 600 | 1.000 | 630 | 1.000 | 850 | 1.000 |
| Total | 7,800 | ----- | 8,230 | ----- | 9,500 | ----- |

In years when Lake Powell EOWY volume is projected to be below the 602(a) storage requirement, and Lake Powell EOWY elevation is equal to or above 3,595 feet msl, then the annual release volume is scheduled at 8.23 maf.

In years when the Lake Powell EOWY elevation is projected to be lower than 3,595 feet msl and equal to or above 3,560 feet msl, then the annual release volume is scheduled at 7.80 maf.

In years when Lake Powell EOWY elevation is projected to be below 3,560 feet msl, the annual release is scheduled at the volume of water required to balance the volumes of Lake Powell and Lake Mead, constrained by being no more than 9.50 maf and no less than 7.80 maf.

#### *A.5.9.6 Preferred Alternative*

Water year releases for Lake Powell under the Preferred Alternative are identical to those of the Basin States and Conservation Before Shortage alternatives.

## A.6 Lake Mead Operation

Lake Mead is operated primarily to meet downstream demands, including downstream depletions (both United States and Mexico) and reservoir regulation requirements. In any month, the rule computes the downstream depletions based on schedules that have been set as input data (or by other rules) and the amount of water necessary to meet the storage targets for downstream Lake Mohave and Lake Havasu and to overcome evaporation losses at those lakes. The rule sets the total release necessary each month from Lake Mead to meet the total downstream demand, taking into account gains and losses below Lake Mead.

The depletions from Lake Mead and downstream of Hoover Dam are affected by the determination of the water supply conditions (Normal, Surplus, or Shortage). Additional rules determine the water supply condition and set the appropriate depletion schedule for the entities affected, as described in Sections A.6.2 and A.6.3.

Under certain conditions, Lake Mead may release water in addition to downstream demand. This condition is termed “flood control” and is guided by the United States Army Corps of Engineers’ (USACE) flood control regulations as contained in the USACE’s Water Control Manual for Flood Control, Hoover Dam and Lake Mead, Colorado River, Nevada and Arizona (Water Control Manual) dated December 1982. These flood control operations and their simulation in the CRSS model are described in Section A.6.1.

## A.6.1 Lake Mead/Hoover Dam Flood Control

There are three flood control procedures currently in effect for different times of the year. These procedures were developed in the original CRSS and are based on the Field Working Agreement between Reclamation and the USACE (United States Army Corps of Engineers 1982). The first procedure is in effect throughout the year. Its objective is to maintain a minimum space of 1.5 maf in Lake Mead, primarily for extreme rain events. This space is referred to as the exclusive flood control space and is represented by the space above elevation 1,219.61 feet msl. The second procedure is used during the period from January through July. The objective during this period is to route the maximum inflow forecast through the reservoir system using specific rates of Hoover Dam discharge, assuming that Lake Mead will fill to elevation 1,219.61 feet msl at the end of July. The third procedure is used during the space building or drawdown period (August through December). The objective during this period is to gradually draw down the reservoir system to meet the total system space requirements in each month in anticipation of the next year’s runoff.

### *A.6.1.1 Exclusive Flood Control Space Requirement*

This requirement states that there must be a minimum space of 1.5 maf in Lake Mead at all times. If the release computed to meet downstream demand results in a Lake Mead storage that would violate this space requirement, the rule computes the additional release necessary to maintain that space.

### *A.6.1.2 January through July Operation*

The flood control policy requires that the maximum forecast be used where that forecast is defined as the estimated inflow volume that, on average, will not be exceeded 19 times out of 20 (a 95 percent non-exceedance). The rule first computes the inflow forecast to Lake Mead by taking the Lake Powell forecast (Section A.5) and adds the long-term, average natural tributary inflows between Lake Powell and Lake Mead. The maximum forecast is then estimated by adding an additional volume (the “forecast error term”) to that inflow forecast. The forecast error term (in maf) is provided in Table A-13, taken from the original CRSS data.

Table A-13
Lake Mead January through July Forecast Error

| Forecast Period | Forecast Error Term (maf) |
|---|---|
| January – July | 4.980 |
| February – July | 4.260 |
| March – July | 3.600 |
| April – July | 2.970 |
| May – July | 2.525 |
| June – July | 2.130 |
| July – July | 0.750 |

The Field Working Agreement defines an iterative algorithm by which the current month's release (in cfs) is determined. Certain release levels are specified, as listed in Table A-14.

Table A-14
Lake Mead Flood Control Release Levels

| Release Level | Release (cfs) | Description |
|---|---|---|
| 1 | 19,000 | Parker Powerplant capacity |
| 2 | 28,000 | Davis Powerplant capacity |
| 3 | 35,000 | Hoover Powerplant capacity (in 1987) |
| 4 | 40,000 | Approximate maximum flow non-damaging to streambed |
| 5 | 73,000 | Hoover Dam controlled discharge capacity |

The flood control release needed for the current month is determined by:

> release needed for the current month = maximum forecast inflow – current storage space in Lake Powell (below 3,700 feet msl) – current storage space in Lake Mead (below 1,229 feet msl) + 1.5 maf (exclusive space) – evaporation and bank storage losses from Lake Powell and Lake Mead – Southern Nevada depletion – future volume of water released (assuming a release level from Table A-14 for the remaining months through July)

If the computed release for the current month is greater than that assumed for the future months, the future level is increased and the current month release is re-computed. The computation stops once the computed release for the current month is less than or equal to that assumed for the future months. If the computed release is greater than the previously assumed level, that release is used for the current month; otherwise, the previously assumed level is used.

The rule sets Lake Mead's release to the flood control release if it is greater than the release previously computed to meet downstream demands.

#### *A.6.1.3 Space Building (August to December)*

The flood control policy states the flood control storage space (in maf) in Lake Mead (storage below elevation 1,229 feet msl) required at the beginning of each month from August through January, as listed in Table A-15.

Table A-15
Lake Mead Flood Control Required Storage Space

| Date | Required Storage Space (maf) |
|---|---|
| August | 1.50 |
| September | 2.27 |
| October | 3.04 |
| November | 3.81 |
| December | 4.58 |
| January | 5.35 |

However, these targets may be reduced to the minimum of 1.5 maf in each month if additional space is available upstream in live storage. Certain upstream reservoirs are specified with a maximum creditable space (in maf) that can be applied towards the total required flood control space. The creditable storage space allowed for each of these reservoirs is listed in Table A-16.

Table A-16
Lake Mead Flood Control Maximum Creditable Storage Space

| Reservoir | Maximum Creditable Storage Space (maf) |
|---|---|
| Powell | 3.8500 |
| Navajo | 1.0359 |
| Blue Mesa | 0.7485 |
| Flaming Gorge plus Fontenelle | 1.5072 |

In each month (July through December), if the release computed to meet downstream demands results in an end-of-month Lake Mead storage that would violate the space requirement adjusted for upstream storage, the rule computes the additional release necessary to maintain that space. However, these releases are constrained to be less than or equal to 28,000 cfs.

## A.6.2 Lower Basin Surplus Strategies

Under the No Action Alternative, the Interim Surplus Guidelines (ISG) are assumed to be in effect through 2016. Beginning in 2017, surpluses are determined based on the 70R Strategy (Section A.6.2.4.). The action alternatives use some or all of the surplus conditions and vary by the duration that each type is in effect. A summary comparison of the surplus strategy for each alternative is provided in Attachment A to this appendix (Table Att. A-2). Surplus schedules by entity are provided in Appendix D. The ISG are specified in the Record of Decision (ROD), Colorado River ISG, Final Environmental Impact Statement, January 2001, and the model implements those as follows:

### *A.6.2.1 Normal Conditions*

If the model determines that neither surplus or shortage conditions exists, the model assigns the Normal schedules to all diversion points in the Lower Basin. The Normal schedules total 7.5 maf of annual consumptive use in the Lower Basin.

### *A.6.2.2 Partial Domestic Surplus*

If the modeled January 1 Lake Mead elevation is at or above 1,125 feet msl and below 1,145 feet msl, the model assigns the Partial Domestic Surplus schedules to Metropolitan Water District of Southern California (MWD) and the Southern Nevada Water Authority (SNWA). All other diversion points remain at Normal schedules. The Partial Domestic Surplus schedules yield the amount of surplus for MWD and SNWA as specified in the ROD, and are documented in the Final Environmental Impact Statement, Implementation Agreement, Inadvertent Overrun and Payback Policy, and Other Federal Actions (SIA-EIS, Bureau of Reclamation 2002).

### *A.6.2.3 Full Domestic Surplus*

If the modeled January 1 Lake Mead elevation is at or above 1,145 feet msl but below the spill avoidance strategy assuming the runoff value of the 70$^{th}$ percentile of exceedance based on the historic record of runoff above Lake Powell (i.e., the 70R Strategy), the model assigns the Full Domestic Surplus schedules to MWD and SNWA. All other diversion points remain at Normal schedules. The Full Domestic Surplus schedules yield the amount of surplus for MWD and SNWA as specified in the ROD, and are documented in the Implementation Agreement Final EIS (Reclamation 2002).

### *A.6.2.4 Quantified Surplus (70R Strategy)*

Under the 70R Strategy, a surplus condition is based on the system space requirement at the beginning of each year. Based on the 70$^{th}$ percentile historical runoff, a normal 7.5 maf delivery to the Lower Division states, the Upper Basin scheduled use, and Lake Powell and Lake Mead volumes at the beginning of the year, the volume of water in excess of the system space requirement at the end of the year is estimated. If that volume is greater than zero, a Surplus is declared. The quantity of the surplus volume (*SurVol*) is computed as follows:

SurVol = (PowellStorage + MeadStorage – maxStorage)* (1 + aveBankStorCoef) + runoff – UBDemand – LBDemand

Where:

| | | |
|---|---|---|
| Powell Storage | = | Lake Powell storage at the beginning of the year |
| Mead Storage | = | Lake Mead storage at the beginning of the year |
| maxStorage | = | maximum combined storage of Lake Powell and Lake Mead that will meet the system space requirement at the beginning of the year, assuming 30% of that requirement will be met by the reservoirs upstream of Lake Powell (computed as live capacity of Lake Powell and Lake Mead – 70% * Lake Mead space requirement at the beginning of the year equal to 5.35 maf = 47.96 maf) |
| aveBankStorCoef | = | average of Lake Powell and Lake Mead bank storage coefficients |
| runoff | = | assumed percentile runoff |
| UBDemand | = | Upper Basin depletion scheduled for the year + the average evaporation loss in the Upper Basin (same as assumed in the 602(a) calculation, 560 kaf) |
| LBDemand | = | sum of depletions below Lake Powell + the evaporation losses in the Lower Basin (average loss of 900 kaf at Lake Mead and computed for Lake Mohave and Lake Havasu, based on target storage) – average gains between Lake Powell and Lake Mead – average gains below Lake Mead |

Once the quantity of surplus volume is known, the model computes each state's share (50 percent to California, 46 percent to Arizona, and 4 percent to Nevada). The model then assigns the Full Domestic Surplus schedules to MWD and SNWA. Arizona's share of the surplus is assigned to the Central Arizona Project (CAP), up to their Full Surplus schedule. If surplus water is still available for California, up to 300 kaf is made available to the Imperial Irrigation District (IID) and the Coachella Valley Water District (CVWD).

#### *A.6.2.5 Flood Control Surplus*

If the modeled January 1 system volumes projects Hoover Dam flood control releases based on the Field Working Agreement between Reclamation and the USACE for the flood control operation of Hoover Dam and Lake Mead (USACE 1982), the model assigns the Full Surplus schedules to MWD, SNWA, CAP, IID, and CVWD. In addition, the model assigns an additional delivery of up to 200 kaf to Mexico. All other diversion points remain at Normal schedules. The Full Domestic Surplus schedules are documented in the Secretarial Implementation Agreement Final EIS (2002).

## A.6.3 Lower Basin Shortage Strategies

A summary comparison of the shortage strategy for each alternative is provided in Attachment A to this appendix (Table Att. A-2).

### *A.6.3.1 No Action Alternative*

In the absence of specific shortage guidelines, modeling assumptions were made that followed assumptions for previous environmental compliance documents. Based on these assumptions a two-level shortage protection strategy was employed. This strategy established the elevations in Lake Mead to be protected and the protection strategy (probabilistic or absolute). Within the two protection levels are two methods or stages for allocating the required shortage amount as explained below. See Section 4.2, Volume I, in this Final EIS for a description of the methodology regarding the shortage sharing assumptions under the two stages of shortage.

In Level 1 protection, the shortage determination is based on comparing the January 1 Lake Mead elevation to a user-input trigger elevation, where the trigger elevations are determined from other modeling studies to protect a significant elevation within a given degree of confidence. The Level 1 shortage trigger elevations are presented in Table A-17.

Table A-17
Level 1 Shortage Trigger Elevations

| Year | Elevations (feet msl) | Year | Elevations (feet msl) | Year | Elevations (feet msl) |
|---|---|---|---|---|---|
| 2008 | 1,079 | 2026 | 1,101 | 2043 | 1,127 |
| 2009 | 1,082 | 2027 | 1,103 | 2044 | 1,129 |
| 2010 | 1,083 | 2028 | 1,104 | 2045 | 1,132 |
| 2011 | 1,084 | 2029 | 1,106 | 2046 | 1,133 |
| 2012 | 1,085 | 2030 | 1,107 | 2047 | 1,135 |
| 2013 | 1,086 | 2031 | 1,108 | 2048 | 1,137 |
| 2014 | 1,086 | 2031 | 1,108 | 2049 | 1,138 |
| 2015 | 1,087 | 2032 | 1,109 | 2050 | 1,140 |
| 2016 | 1,088 | 2033 | 1,110 | 2051 | 1,142 |
| 2017 | 1,090 | 2034 | 1,112 | 2052 | 1,144 |
| 2018 | 1,091 | 2035 | 1,113 | 2053 | 1,145 |
| 2019 | 1,093 | 2036 | 1,114 | 2054 | 1,147 |
| 2020 | 1,094 | 2037 | 1,116 | 2055 | 1,149 |
| 2021 | 1,095 | 2038 | 1,117 | 2056 | 1,151 |
| 2022 | 1,096 | 2039 | 1,119 | 2057 | 1,152 |
| 2023 | 1,097 | 2040 | 1,120 | 2058 | 1,154 |
| 2024 | 1,098 | 2041 | 1,123 | 2059 | 1,156 |
| 2025 | 1,100 | 2042 | 1,125 | 2060 | 1,157 |

Under Level 1 protection, if Lake Mead's elevation at the beginning of the year is less than the trigger elevation, a Stage 1 shortage is declared and certain Lower Basin depletions are reduced. The shortage remains in effect for that calendar year. A Stage 1 shortage is defined as a shortage of magnitude less than that which would cause Arizona 4$^{th}$ priority uses to be reduced to zero.

Level 1 protection of elevation 1,050 feet msl (minimum water level for operation of Southern Nevada's upper diversion intake and minimum power pool) was used in this study. Trigger elevations were input to protect each elevation with an approximately 80 percent probability; however, actual model simulations showed that the protection was less, approximately 70 percent over the entire simulation period. Under Level 1 protection a Stage 1 shortage is declared and the CAP depletion is set to 1.0 maf, and other Arizona 4$^{th}$ priority uses are reduced proportionately, as described in the equations below.

$$CAP_{short} = CAP_{norm} - 1.0maf$$

$$OtherAZP4_{short} = (CAP_{short} * \frac{CAP_{norm} + OtherAZP4_{norm}}{CAP_{norm}}) - CAP_{short}$$

Where: the subscript norm denotes the normal depletion amount and the subscript short denotes the shortage amount. The shortage amount is subtracted from the normal depletion amount to solve for the shorted depletion amount.

The percent shortage applied to each Arizona 4$^{th}$ priority in OtherAZP4 is computed as a fraction of their normal use divided by the total other Arizona 4$^{th}$ priority use.

Other Lower Basin depletions are reduced according to the percents presented in Table A-18.

Table A-18
Modeling Assumptions for Distribution of Stage 1 Shortages[a]

| Entity | Percentage of Total Lower Basin Shortage | Calculation |
|---|---|---|
| Arizona[b] | 80 | ♦ Computed assuming that Arizona takes the remaining amount of shortage after Nevada and Mexico take their respective shares<br>♦ 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 apportionment to the total apportionments of the Lower Division states and Mexico<br>♦ Calculated as: 0.3 maf / 9.0 maf – 0.0333 or 3.33 percent |
| Mexico [1] | 16.67 | ♦ Computed as a ratio of Mexico's allotment to the total allotments of the Lower Division states and Mexico<br>♦ Calculated as: 1.5 maf / 9.0 maf = 0.1667 or 16.67 percent |

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

Mexico and SNWA are reduced by 16.67 and 3.33 percent of the total Stage 1 shortage, respectively. The MWD does not take a Stage 1 shortage. The total Stage 1 shortage is computed as:

$$TotalStage1Short = \frac{CAP_{short} + OtherAZP4_{short}}{100\% - (3.33\% + 16.67\%)}$$

Under Level 2 protection, the shortage required to keep Lake Mead above elevation 1,000 feet msl (minimum elevation for operation of Southern Nevada's lower diversion intake) is computed and distributed among Lower Basin users as described in Table A-19. In each month, January through September, a rule estimates the end-of-April through end-of-September Lake Mead elevation (using Stage 1 shortage schedules and normal schedules for other users). April through September is generally the high demand period from Lake Mead. If in any month during the high demand period the estimated Lake Mead elevation is below 1,000 feet msl, Arizona 4$^{th}$ priority users are reduced to zero and SNWA and Mexico take their respective percents of the total shortage for the current month. This type of pre-emptive shortage approach is required to avoid the

[1] 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. However, in order to assess the potential effects of the proposed federal action in this Final EIS, certain modeling assumptions (discussed in Chapter 2, Volume I) are used that display projected water deliveries to Mexico. 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.

situation when, in a given month, the shortage required to keep Lake Mead above elevation of 1,000 feet msl is greater than the available demand. If, in the current month the shortage required to protect elevation 1,000 feet msl does not require Arizona 4th priority users to be reduced to zero, the lesser shortage amount is allocated.

If, in any month additional shortage beyond Stage 1 is required to protect Lake Mead elevation of 1,000 feet msl, a Stage 2 shortage is declared. The Stage 2 shortage amount is the amount in excess of the Stage 1 shortage amount required to protect elevation 1,000 feet msl absolutely. In a Stage 2 shortage Mexico and SNWA are further reduced and Arizona 2nd and 3rd priority uses and MWD are reduced. These entities are reduced according to the percentage values provided in Table A-19.

Table A-19
Modeling Assumptions for Distribution of Stage 2 Shortages[1]
No Action Alternative

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

*1. These modeling assumptions do not reflect policy decisions and are not intended to constitute an interpretation or application of the 1944 Treaty. They have been developed for comparison of the alternatives.*

The maximum amount of Stage 2 shortage that can be applied is dictated by MWD demand. If the amount of Stage 2 shortage required is greater then MWD demand, then the Stage 2 shortage amount becomes

$$TotalStage2Short_{Constrained} = \frac{MWD_{norm}}{100\% - (3.33\% + 16.67\% + AZP2and3Short\%)}$$

In the event that a Stage 2 shortage is constrained and not fully allocated, Lake Mead elevation decline to below 1,000 feet msl. If Lake Mead elevation drops below 1,000 feet msl, SNWA is reduced to zero (due to physical limitations) for the current month and the other users maintain their shortage amounts as if SNWA had not been completely reduced.

#### *A.6.3.2 Basin States Alternative*

The Basin States Alternative provides discrete stepped levels of shortage associated with specific Lake Mead elevations. These shortage amounts and the corresponding elevations are provided in Attachment A to this appendix (Table Att. A-2). The maximum shortage is 600 kaf below elevation 1,025 feet msl. The shortage determination is based on comparing the January 1 Lake Mead elevation to the specific Lake Mead trigger elevations. If Lake Mead's elevation at the beginning of the year is less than the trigger elevation, a shortage of the corresponding amount is declared and certain Lower Basin depletions are reduced. The shortage remains in effect for that calendar year. The shortage is allocated according to the percentages used under a Stage 1 shortage in the No Action Alternative provided in Table A-19. As under the No Action Alternative, SNWA is reduced to zero for the current month if, in the previous month Lake Mead elevation is below 1,000 feet msl.

#### *A.6.3.3 Conservation Before Shortage Alternative*

The shortage strategy under the Conservation Before Shortage Alternative is identical to the Level 2 shortage protection in the No Action Alternative. The Level 1 shortage protection in the No Action Alternative is replaced with various levels of voluntary conservation in the Conservation Before Shortage Alternative. Modeling assumptions regarding the voluntary conservation portion of this alternative are located in Appendix M. The amounts of voluntary conservation and the corresponding reservoir elevations are identical to the shortage amounts and corresponding reservoir elevations under the Basin States Alternative.

#### *A.6.3.4 Water Supply Alternative*

There is no shortage strategy in place in the Water Supply Alternative. The only reduction in use occurs when, in the previous month Lake Mead elevation is below 1,000 feet msl. In this event SNWA is reduced to zero for the current month.

#### *A.6.3.5 Reservoir Storage Alternative*

Like the Basin States Alternative, the Reservoir Storage Alternative provides discrete stepped levels of shortage associated with specific Lake Mead elevations. These shortage amounts and the corresponding elevations are provided in Attachment A to this appendix (Table Att. A-2). The maximum shortage is 1,200 kaf below elevation 1,025 feet msl. Shortage determination and allocation occurs in the same way as under the Basin States Alternative.

#### *A.6.3.6 Preferred Alternative*

The Preferred Alternative utilizes identical shortage assumptions as the Basin States Alternative.

### A.6.4 Lake Mead Storage and Delivery of Conserved System and/or Non-system Water

Detailed modeling assumptions regarding the Lake Mead storage and delivery mechanism for conserved system and/or non-system water as part of the Basin States, Conservation Before Shortage, and Reservoir Storage alternatives, and the Preferred Alternative, is provided in Appendix M.

## A.7 Summary Comparison of Lake Powell and Lake Mead Operations

A summary comparison of Lake Powell and Lake Mead operations under the No Action Alternative and the action alternatives is provided in Attachment A to this appendix (Tables Att. A-1 and Att. A-2, respectively).

## A.8 Lake Mohave and Lake Havasu Operations

Lake Mohave and Lake Havasu are operated to meet user-specified target storages at the end of each month. This operation remained consistent for all alternatives. The storage targets and the corresponding elevations for Lake Mohave and Lake Havasu are presented in Tables B-4 and B-5, respectively, in Appendix B.

## A.9 Energy Generation

RiverWare™ includes a variety of methods that can be chosen to compute power generation. All methods compute power and energy on a monthly basis. The following sections describe the methods used to compute power at Glen Canyon Dam, Hoover Dam, Davis Dam and Parker Dam.

### A.9.1 Glen Canyon Dam

The computation of power and energy generated at Glen Canyon Dam is based on the turbine release for the current month and a power coefficient which is a function of the turbine release and operating head. Turbine release is the lesser value of the maximum power release or the result of outflow minus spill. The power coefficient is computed through table interpolation given the operating head. The table used for interpolation is chosen based on the turbine release and can represent either flow through the turbine for most efficient power generation or the maximum flow through the turbine. The power coefficient may also be an intermediate value, computed through interpolation of both tables, if the turbine release is between the most efficient for power generation and the maximum flow through the turbine.

Once the power coefficient is computed, power generated for the current month is computed as

$$Power = PowerCoefficient * Turbine\ Release$$

Energy is calculated as the power multiplied by the length of the month in hours.

If the previous month's elevation is less than 3,490 feet msl, there is no power or energy generated for the current month. This elevation reflects the minimum power pool elevation at Lake Powell.

### A.9.2 Hoover Dam

The method that computes power and energy generated at the Hoover Dam assumes two levels of power generation. The lower level of generation occurs at base flow while the upper level occurs at peak flow. The method computes the fraction of the month that the powerplant is operated at peak flow and base flow. The peaking flow is the most efficient flow through the turbines for the current operating head while the baseflow represents the minimum flow through the turbines to produce energy.

The base flow and corresponding power generation is based on the outflow for the current month. The peak flow must be computed through an iterative procedure using operating head, tailwater elevation and turbine release. The initial turbine release is assumed to be that corresponding to maximum power production. Tailwater elevation at Hoover Dam is computed as function of Lake Mohave elevation, and Hoover Dam release.

The monthly Hoover Dam release volume at base flow is computed by applying the base flow over the month. The monthly release volume at peak flow is computed as

$$PeakFlowVolume = TurbineReleaseVolume - BaseFlowVolume$$

Next, the number of hours required for operation at base and peak flows are then computed as

$$PeakHours = \frac{PeakFlowVolume}{(PeakFlow - BaseFlow) * 3600}$$

$$BaseHours = \frac{SecondsInMonth}{3600} - PeakHours$$

where 3600 is the amount of seconds per hour.

If the peak hours are greater than the length of the month, the peak hours value is set equal to the length of the month and base hours value is set to zero. The peak and base hours are then multiplied by the powerplant capacity at each level and added together to obtain the total energy produced for the month. Power is computed as the energy divided by the length of the month in hours.

The algorithm described above allows generation at elevations below 1,050 feet msl, the minimum power pool at Lake Mead. According to the algorithm, power is generated as long as the minimum operating head of 360 feet is available, corresponding to an elevation of about 1,011 feet msl. Because there is no operating experience at these elevations, it is impossible to verify if CRSS mimics the actual turbine performance at such low heads. It is therefore critical to view energy results from CRSS in a relative manner and not in a strict numeric sense.

### A.9.3 Davis Dam

The method that computes power and energy generation at Davis Dam is the same method used for Hoover Dam.

### A.9.4 Parker Dam

The method that computes power and energy generation at Parker Dam is the same method used for Hoover Dam.

## A.10 Reservoir Evaporation

Evaporation at Lake Powell and Lake Mead is calculated in CRSS by multiplying the reservoir surface area by user-supplied evaporation coefficients. Specifically, the average reservoir surface area over the previous and current month (in acres) is multiplied by the monthly evaporation coefficient (in feet per month) to produce the rate of evaporation in acre-feet per month as specified by the following equation:

$$Evaporation(t) = EvaporationCoefficient(t) * \frac{(SurfaceArea(t) + SurfaceArea(t-1))}{2} * TimestepLength$$

Where: $t$ = current time-step

$t\text{-}1$ = previous time-step

The monthly evaporation coefficients for Lake Powell and Lake Mead are presented in Table A-20.

Table A-20
Monthly Evaporation Coefficients for Lake Powell and Lake Mead

| Month | Evaporation Coefficient (feet/month) | |
|---|---|---|
| | Lake Powell | Lake Mead |
| January | 0.198 | 0.36 |
| February | 0.186 | 0.33 |
| March | 0.233 | 0.37 |
| April | 0.265 | 0.46 |
| May | 0.359 | 0.53 |
| June | 0.411 | 0.64 |
| July | 0.466 | 0.80 |
| August | 0.478 | 0.85 |
| September | 0.415 | 0.70 |
| October | 0.375 | 0.51 |
| November | 0.312 | 0.51 |
| December | 0.261 | 0.44 |

## A.11 Model Input and Simulation

CRSS is used to simulate the future conditions of the system on a monthly time step. Output data include reservoir storage, releases from dams, hydroelectric generation, etc. Input data for the model includes monthly natural flow at 29 nodes throughout the Colorado River system. Input data also includes physical parameters (e.g., individual reservoir storage capacity, evaporation rates, and reservoir release capabilities), initial reservoir conditions, and the diversion and depletion schedules for entities in the Colorado River Basin States and Mexico. Operating rules for current or proposed operating policies are considered input.

Although several methods are available for ascertaining the range of possible future inflows, Reclamation utilized the existing historical record of natural flows to create several distinct and synthetic hydrologic sequences that are then used in a series of simulations. For this process, Reclamation used a particular technique for sampling from the historical record known as the Indexed Sequential Method, or ISM (Reclamation 1985; Ouarda et al. 1997). Each future hydrologic sequence is generated from the historical natural flow record by "cycling" through the record. This method produces the "n" possible flow sequences, where n corresponds to the number of years in the flow data set. Using the historical natural flow data from 1906 through 2005 with ISM results in a set of 100 separate simulations referred to as "traces." This enables an evaluation of proposed criteria over a broad range of possible future hydrologic conditions. Evaluations typically include all 100 traces using statistical techniques.

## A.12 Model Uncertainty

Using ISM, CRSS generates a wide range of hydrologic possibilities which include periods of extreme drought and periods of much above average flow, allowing evaluation of the proposed federal action under a wide range of future flows. However, it is possible that future flows may include periods of wet or dry conditions that are outside of all the possible sequences seen in the historical record. Appendix N provides alternate hydrologic inflow scenarios for comparison with the 1906 through 2005 natural flow record using ISM.

Model output is also sensitive to input diversion and depletion schedules. The best available data for future diversions and depletions are input to CRSS (Appendix C and Appendix D). Actual future depletion schedules, especially when simulating system conditions far into the future (beyond about 20 years from the present) may differ.

## A.13 References

Bureau of Reclamation. 1985. Colorado River Simulation System: System Overview. Denver, CO.

Bureau of Reclamation. 1996. *Replacement of the Colorado River Simulation System*. Draft Report. Lower Colorado Region, Boulder City, NV.

Bureau of Reclamation. 1998. *CRSSez: Annual Colorado River System Simulation Model, Overview and Users Manual*. Lower Colorado Region, Boulder City, NV.

Bureau of Reclamation. 2001. *Record of Decision, Colorado River Interim Surplus Guidelines, Final Environmental Impact Statement*. Lower Colorado Region, Boulder City, NV.

Bureau of Reclamation. 2002. *Final Environmental Impact Statement for the Secretarial Implementation Agreement, Inadvertent Overrun and Payback Policy, and Related Federal Actions*. October. Lower Colorado Region, Boulder City, NV.

Bureau of Reclamation. 2005. *CRSS-Lite Overview and Users' Manual.* Lower Colorado Region. Boulder City, NV.

Fulp, T. 1999. *Colorado River Operations*, paper presented at Climate Change Symposium, Cooperative Institute for Research in Environmental Systems (CIRIES). Boulder, CO.

Fulp, T., B. Vickers, B. Williams, and D. King. 1999. *Replacing an Institutional Model: The Colorado River Simulation System Example*. Presented at the WaterPower 99 conference, American Society of Civil Engineers. Las Vegas, NV.

Ouarda, T., J.W. Labadie, and D.G. Fontane. 1997. *Indexed Sequential Hydrologic Modeling for Hydropower Capacity Estimation*. *Journal of the American Water Resources Association*, 33(6):1337-1349.

U.S. Army Corps of Engineers. 1982. *Water Control Manual for Flood Control: Hoover Dam and Lake Mead, Colorado River*. Los Angeles, CA.

Zagona, E., T. Fulp, R. Shane, T. Magee, and H. Goranflo. 2001. *RiverWare™: A Generalized Tool for Complex Reservoir Systems Modeling*. *Journal of the American Water Resources Association*. 37(4):913–929.

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# Attachment A

## Summary Comparison of Lake Powell and Lake Mead Operations Under the No Action Alternative and the Action Alternatives

This attachment to Appendix A contains the summary comparison table of the Lake Powell and Lake Mead operational strategies for each alternative.

Table Att. A-1
Lake Powell
Comparison of Alternatives
Coordinated Reservoir Operations Element of the Proposed Federal Action

| Lake Powell Elevation (feet msl) | No Action Alternative | Basin States Alternative | Conservation Before Shortage Alternative | Water Supply Alternative | Reservoir Storage Alternative | Preferred Alternative | Lake Powell Storage (maf) |
|---|---|---|---|---|---|---|---|
| **3,700** | Equalize, avoid spills or release 8.23 maf | Equalize, avoid spills or release 8.23 maf | Equalize, avoid spills or release 8.23 maf | Equalize, avoid spills or release 8.23 maf | Equalize, avoid spills or release 8.23 maf | Equalize, avoid spills or release 8.23 maf | **24.3** |
| **Equalization** | **602(a)** | **Upper Equalization Line** | **Upper Equalization Line** | **602(a)** | **602(a)** | **Upper Equalization Line** | **Equalization** |
| | Release 8.23 maf | Release 8.23 maf; if Lake Mead < 1,075 feet msl, balance contents with a min/max release of 7.0 and 9.0 maf | Release 8.23 maf; if Lake Mead < 1,075 feet msl, balance contents with a min/max release of 7.0 and 9.0 maf | Release 8.23 maf; if Lake Mead < 1,075 feet msl, balance contents with a min/max release of 7.0 and 9.5 maf | Release 8.23 maf | Release 8.23 maf; if Lake Mead < 1,075 feet msl, balance contents with a min/max release of 7.0 and 9.0 maf | |
| **3,595** | | | | | | | **11.3** |
| | | | | | Release 7.8 maf | | |
| **3,575** | | | | | | | **9.5** |
| | | Release 7.48 maf; if Lake Mead < 1,025 feet msl, release 8.23 maf | Release 7.48 maf; if Lake Mead < 1,025 feet msl, release 8.23 maf | Balance contents with a min/max release of 7.0 and 9.5 maf | | Release 7.48 maf; if Lake Mead < 1,025 feet msl, release 8.23 maf | |
| **3,560** | | | | | | | **8.3** |
| | | | | | Balance contents with a min/max release of 7.8 and 9.5 maf | | |
| **3,525** | | | | | | | **5.9** |
| | | Balance contents with a min/max release of 7.0 and 9.5 maf | Balance contents with a min/max release of 7.0 and 9.5 maf | | | Balance contents with a min/max release of 7.0 and 9.5 maf | |
| **3,490** | | | | | | | **4.0** |
| **3,370** | | | | | | | **0** |

Table Att. A-2
Lake Mead
Comparison of Alternatives
Coordinated Reservoir Operations Element of the Proposed Federal Action

| Lake Mead Elevation (feet msl) | No Action Alternative | Basin States Alternative | Conservation Before Shortage Alternative | Water Supply Alternative | Reservoir Storage Alternative | Preferred Alternative | Lake Mead Storage (maf) |
|---|---|---|---|---|---|---|---|
| 1,220 | Flood Control or 70R Surplus | Flood Control or 70R Surplus | Flood Control or 70R Surplus | Flood Control or 70R Surplus | Flood Control or 70R Surplus | Flood Control or 70R Surplus | 25.9 |
| 1,200 | Full Domestic Surplus (through 2016) | Domestic Surplus | Domestic Surplus | Full Domestic Surplus | Normal Operations | Domestic Surplus | 22.9 |
| 1,145 | Partial Domestic Surplus (through 2016) | Normal Operations | Normal Operations | Partial Domestic Surplus | | Normal Operations | 15.9 |
| 1,125 | Normal Operations | | | Normal Operations | | | 13.9 |
| 1,100 | Shortage 80 percent Protection of elevation 1,050 feet msl | | | | Shortage 500[1] kaf | | 11.5 |
| 1,075 | | Shortage 333 kaf[1] | Voluntary Conservation | | Shortage 667[1] kaf | Shortage 333 kaf[1] | 9.4 |
| 1,050 | | Shortage 417 kaf[1] | | | Shortage 833[1] kaf | Shortage 417 kaf[1] | 7.5 |
| 1,025 | | Shortage 500 kaf[1] and Consultation[2] | | | Shortage 1,000[1] kaf | Shortage 500 kaf[1] and Consultation[2] | 5.8 |
| 1,000 | Shortage Absolute Protection of elevation 1,000 feet msl | | Shortage Absolute Protection of elevation 1,000 feet msl | | | | 4.3 |
| 895 | | | | | | | 0 |

[1] These are amounts of shortage (i.e., reduced deliveries in the United States). As in the Draft EIS, the Final EIS includes modeling assumptions that identify water deliveries to Mexico pursuant to the 1944 Treaty.
[2] If Lake Mead falls below elevation 1,025, the Department will initiate efforts to develop additional guidelines for shortages at lower Lake Mead elevations.

# Attachment B

## Elevation, Capacity, and Surface Area Relationships for Lake Powell and Lake Mead

This attachment to Appendix A contains tables used in the CRSS model which present the corresponding values for the range of operational elevations at Lake Powell and Lake Mead to the live capacity, total capacity, and surface area for each respective reservoir.

Table Att. B-1
Lake Powell Elevation to Storage Volume and Surface Area Relationships

| Elevation (feet msl) | Volume Live Capacity (af) | Volume Total Capacity (af) | Surface Area (acres) | | Elevation (feet msl) | Volume Live Capacity (af) | Volume Total Capacity (af) | Surface Area (acres) |
|---|---|---|---|---|---|---|---|---|
| 3,370 | 0 | 1,895,000 | 20,303 | | 3,410 | 964,242 | 2,859,242 | 28,054 |
| 3,371 | 20,393 | 1,915,393 | 20,483 | | 3,411 | 992,396 | 2,887,396 | 28,253 |
| 3,372 | 40,966 | 1,935,966 | 20,663 | | 3,412 | 1,020,748 | 2,915,748 | 28,452 |
| 3,373 | 61,719 | 1,956,719 | 20,843 | | 3,413 | 1,049,299 | 2,944,299 | 28,651 |
| 3,374 | 82,651 | 1,977,651 | 21,023 | | 3,414 | 1,078,050 | 2,973,050 | 28,850 |
| 3,375 | 103,764 | 1,998,764 | 21,203 | | 3,415 | 1,106,999 | 3,001,999 | 29,049 |
| 3,376 | 125,056 | 2,020,056 | 21,382 | | 3,416 | 1,136,148 | 3,031,148 | 29,248 |
| 3,377 | 146,529 | 2,041,529 | 21,562 | | 3,417 | 1,165,496 | 3,060,496 | 29,448 |
| 3,378 | 168,181 | 2,063,181 | 21,742 | | 3,418 | 1,195,043 | 3,090,043 | 29,647 |
| 3,379 | 190,013 | 2,085,013 | 21,922 | | 3,419 | 1,224,790 | 3,119,790 | 29,846 |
| 3,380 | 212,025 | 2,107,025 | 22,102 | | 3,420 | 1,254,735 | 3,149,735 | 30,045 |
| 3,381 | 234,226 | 2,129,226 | 22,300 | | 3,421 | 1,284,896 | 3,179,896 | 30,278 |
| 3,382 | 256,625 | 2,151,625 | 22,498 | | 3,422 | 1,315,290 | 3,210,290 | 30,510 |
| 3,383 | 279,222 | 2,174,222 | 22,696 | | 3,423 | 1,345,917 | 3,240,917 | 30,743 |
| 3,384 | 302,017 | 2,197,017 | 22,894 | | 3,424 | 1,376,777 | 3,271,777 | 30,976 |
| 3,385 | 325,010 | 2,220,010 | 23,092 | | 3,425 | 1,407,869 | 3,302,869 | 31,208 |
| 3,386 | 348,201 | 2,243,201 | 23,290 | | 3,426 | 1,439,194 | 3,334,194 | 31,441 |
| 3,387 | 371,590 | 2,266,590 | 23,488 | | 3,427 | 1,470,751 | 3,365,751 | 31,674 |
| 3,388 | 395,177 | 2,290,177 | 23,686 | | 3,428 | 1,502,541 | 3,397,541 | 31,907 |
| 3,389 | 418,962 | 2,313,962 | 23,884 | | 3,429 | 1,534,564 | 3,429,564 | 32,139 |
| 3,390 | 442,945 | 2,337,945 | 24,082 | | 3,430 | 1,566,820 | 3,461,820 | 32,372 |
| 3,391 | 467,126 | 2,362,126 | 24,280 | | 3,431 | 1,599,308 | 3,494,308 | 32,605 |
| 3,392 | 491,505 | 2,386,505 | 24,478 | | 3,432 | 1,632,029 | 3,527,029 | 32,837 |
| 3,393 | 516,082 | 2,411,082 | 24,676 | | 3,433 | 1,664,983 | 3,559,983 | 33,070 |
| 3,394 | 540,857 | 2,435,857 | 24,874 | | 3,434 | 1,698,170 | 3,593,170 | 33,303 |
| 3,395 | 565,830 | 2,460,830 | 25,072 | | 3,435 | 1,731,589 | 3,626,589 | 33,535 |
| 3,396 | 591,001 | 2,486,001 | 25,270 | | 3,436 | 1,765,241 | 3,660,241 | 33,768 |
| 3,397 | 616,370 | 2,511,370 | 25,468 | | 3,437 | 1,799,125 | 3,694,125 | 34,001 |
| 3,398 | 641,937 | 2,536,937 | 25,666 | | 3,438 | 1,833,242 | 3,728,242 | 34,234 |
| 3,399 | 667,702 | 2,562,702 | 25,864 | | 3,439 | 1,867,592 | 3,762,592 | 34,466 |
| 3,400 | 693,665 | 2,588,665 | 26,062 | | 3,440 | 1,902,175 | 3,797,175 | 34,699 |
| 3,401 | 719,827 | 2,614,827 | 26,261 | | 3,441 | 1,937,016 | 3,832,016 | 34,982 |
| 3,402 | 746,187 | 2,641,187 | 26,460 | | 3,442 | 1,972,139 | 3,867,139 | 35,265 |
| 3,403 | 772,747 | 2,667,747 | 26,659 | | 3,443 | 2,007,546 | 3,902,546 | 35,548 |
| 3,,404 | 799,506 | 2,694,506 | 26,859 | | 3,444 | 2,043,236 | 3,938,236 | 35,831 |
| 3,405 | 826,464 | 2,721,464 | 27,058 | | 3,445 | 2,079,209 | 3,974,209 | 36,115 |
| 3,406 | 853,622 | 2,748,622 | 27,257 | | 3,446 | 2,115,465 | 4,010,465 | 36,398 |
| 3,407 | 880,978 | 2,775,978 | 27,456 | | 3,447 | 2,152,004 | 4,047,004 | 36,681 |
| 3,408 | 908,534 | 2,803,534 | 27,655 | | 3,448 | 2,188,826 | 4,083,826 | 36,964 |
| 3,409 | 936,289 | 2,831,289 | 27,854 | | 3,449 | 2,225,932 | 4,120,932 | 37,247 |

Table Att. B-1
Lake Powell Elevation to Storage Volume and Surface Area Relationships

| Elevation (feet msl) | Volume Live Capacity (af) | Volume Total Capacity (af) | Surface Area (acres) | | Elevation (feet msl) | Volume Live Capacity (af) | Volume Total Capacity (af) | Surface Area (acres) |
|---|---|---|---|---|---|---|---|---|
| 3,450 | 2,263,320 | 4,158,320 | 37,530 | | 3,490 | 3,997,163 | 5,892,163 | 49,330 |
| 3,451 | 2,300,992 | 4,195,992 | 37,813 | | 3,491 | 4,046,646 | 5,941,646 | 49,636 |
| 3,452 | 2,338,946 | 4,233,946 | 38,096 | | 3,492 | 4,096,435 | 5,991,435 | 49,942 |
| 3,453 | 2,377,184 | 4,272,184 | 38,379 | | 3,493 | 4,146,529 | 6,041,529 | 50,247 |
| 3,454 | 2,415,705 | 4,310,705 | 38,662 | | 3,494 | 4,196,929 | 6,091,929 | 50,553 |
| 3,455 | 2,454,509 | 4,349,509 | 38,946 | | 3,495 | 4,247,634 | 6,142,634 | 50,858 |
| 3,456 | 2,493,596 | 4,388,596 | 39,229 | | 3,496 | 4,298,645 | 6,193,645 | 51,164 |
| 3,457 | 2,532,966 | 4,427,966 | 39,512 | | 3,497 | 4,349,962 | 6,244,962 | 51,469 |
| 3,458 | 2,572,619 | 4,467,619 | 39,795 | | 3,498 | 4,401,584 | 6,296,584 | 51,775 |
| 3,459 | 2,612,556 | 4,507,556 | 40,078 | | 3,499 | 4,453,512 | 6,348,512 | 52,080 |
| 3,460 | 2,652,775 | 4,547,775 | 40,361 | | 3,500 | 4,505,745 | 6,400,745 | 52,386 |
| 3,461 | 2,693,284 | 4,588,284 | 40,657 | | 3,501 | 4,558,308 | 6,453,308 | 52,741 |
| 3,462 | 2,734,088 | 4,629,088 | 40,952 | | 3,502 | 4,611,226 | 6,506,226 | 53,095 |
| 3,463 | 2,775,189 | 4,670,189 | 41,248 | | 3,503 | 4,664,498 | 6,559,498 | 53,450 |
| 3,464 | 2,816,585 | 4,711,585 | 41,544 | | 3,504 | 4,718,125 | 6,613,125 | 53,804 |
| 3,465 | 2,858,276 | 4,753,276 | 41,840 | | 3,505 | 4,772,106 | 6,667,106 | 54,159 |
| 3,466 | 2,900,264 | 4,795,264 | 42,135 | | 3,506 | 4,826,442 | 6,721,442 | 54,513 |
| 3,467 | 2,942,547 | 4,837,547 | 42,431 | | 3,507 | 4,881,132 | 6,776,132 | 54,868 |
| 3,468 | 2,985,125 | 4,880,125 | 42,727 | | 3,508 | 4,936,177 | 6,831,177 | 55,222 |
| 3,469 | 3,028,000 | 4,923,000 | 43,022 | | 3,509 | 4,991,576 | 6,886,576 | 55,577 |
| 3,470 | 3,071,170 | 4,966,170 | 43,318 | | 3,510 | 5,047,330 | 6,942,330 | 55,931 |
| 3,471 | 3,114,636 | 5,009,636 | 43,614 | | 3,511 | 5,103,438 | 6,998,438 | 56,286 |
| 3,472 | 3,158,397 | 5,053,397 | 43,909 | | 3,512 | 5,159,901 | 7,054,901 | 56,640 |
| 3,473 | 3,202,455 | 5,097,455 | 44,205 | | 3,513 | 5,216,718 | 7,111,718 | 56,994 |
| 3,474 | 3,246,808 | 5,141,808 | 44,501 | | 3,514 | 5,273,890 | 7,168,890 | 57,349 |
| 3,475 | 3,291,456 | 5,186,456 | 44,797 | | 3,515 | 5,331,416 | 7,226,416 | 57,704 |
| 3,476 | 3,336,401 | 5,231,401 | 45,092 | | 3,516 | 5,389,297 | 7,284,297 | 58,058 |
| 3,477 | 3,381,641 | 5,276,641 | 45,388 | | 3,517 | 5,447,532 | 7,342,532 | 58,412 |
| 3,478 | 3,427,176 | 5,322,176 | 45,684 | | 3,518 | 5,506,122 | 7,401,122 | 58,767 |
| 3,479 | 3,473,008 | 5,368,008 | 45,979 | | 3,519 | 5,565,066 | 7,460,066 | 59,122 |
| 3,480 | 3,519,135 | 5,414,135 | 46,275 | | 3,520 | 5,624,365 | 7,519,365 | 59,476 |
| 3,481 | 3,565,563 | 5,460,563 | 46,581 | | 3,521 | 5,684,034 | 7,579,034 | 59,863 |
| 3,482 | 3,612,296 | 5,507,296 | 46,886 | | 3,522 | 5,744,090 | 7,639,090 | 60,249 |
| 3,483 | 3,659,335 | 5,554,335 | 47,192 | | 3,523 | 5,804,532 | 7,699,532 | 60,635 |
| 3,484 | 3,706,679 | 5,601,679 | 47,497 | | 3,524 | 5,865,361 | 7,760,361 | 61,022 |
| 3,485 | 3,754,329 | 5,649,329 | 47,803 | | 3,525 | 5,926,576 | 7,821,576 | 61,409 |
| 3,486 | 3,802,285 | 5,697,285 | 48,108 | | 3,526 | 5,988,178 | 7,883,178 | 61,795 |
| 3,487 | 3,850,546 | 5,745,546 | 48,414 | | 3,527 | 6,050,166 | 7,945,166 | 62,181 |
| 3,488 | 3,899,113 | 5,794,113 | 48,719 | | 3,528 | 6,112,541 | 8,007,541 | 62,568 |
| 3,489 | 3,947,985 | 5,842,985 | 49,025 | | 3,529 | 6,175,302 | 8,070,302 | 62,955 |

Table Att. B-1
Lake Powell Elevation to Storage Volume and Surface Area Relationships

| Elevation (feet msl) | Volume Live Capacity (af) | Volume Total Capacity (af) | Surface Area (acres) | | Elevation (feet msl) | Volume Live Capacity (af) | Volume Total Capacity (af) | Surface Area (acres) |
|---|---|---|---|---|---|---|---|---|
| 3,530 | 6,238,450 | 8,133,450 | 63,341 | | 3,570 | 9,107,080 | 11,002,080 | 80,824 |
| 3,531 | 6,301,984 | 8,196,984 | 63,727 | | 3,571 | 9,188,146 | 11,083,146 | 81,308 |
| 3,532 | 6,365,905 | 8,260,905 | 64,114 | | 3,572 | 9,269,697 | 11,164,697 | 81,793 |
| 3,533 | 6,430,212 | 8,325,212 | 64,501 | | 3,573 | 9,351,731 | 11,246,731 | 82,277 |
| 3,534 | 6,494,906 | 8,389,906 | 64,887 | | 3,574 | 9,434,250 | 11,329,250 | 82,761 |
| 3,535 | 6,559,986 | 8,454,986 | 65,274 | | 3,575 | 9,517,254 | 11,412,254 | 83,246 |
| 3,536 | 6,625,453 | 8,520,453 | 65,660 | | 3,576 | 9,600,741 | 11,495,741 | 83,730 |
| 3,537 | 6,691,306 | 8,586,306 | 66,047 | | 3,577 | 9,684,713 | 11,579,713 | 84,214 |
| 3,538 | 6,757,546 | 8,652,546 | 66,433 | | 3,578 | 9,769,170 | 11,664,170 | 84,698 |
| 3,539 | 6,824,172 | 8,719,172 | 66,820 | | 3,,579 | 9,854,110 | 11,749,110 | 85,183 |
| 3,540 | 6,891,185 | 8,786,185 | 67,206 | | 3,580 | 9,939,535 | 11,834,535 | 85,667 |
| 3,541 | 6,958,610 | 8,853,610 | 67,645 | | 3,581 | 10,025,445 | 11,920,445 | 86,153 |
| 3,542 | 7,026,475 | 8,921,475 | 68,083 | | 3,582 | 10,111,841 | 12,006,841 | 86,639 |
| 3,543 | 7,094,777 | 8,989,777 | 68,522 | | 3,583 | 10,198,723 | 12,093,723 | 87,125 |
| 3,544 | 7,163,519 | 9,058,519 | 68,961 | | 3,584 | 10,286,091 | 12,181,091 | 87,611 |
| 3,545 | 7,232,699 | 9,127,699 | 69,400 | | 3,585 | 10,373,945 | 12,268,945 | 88,097 |
| 3,546 | 7,302,319 | 9,197,319 | 69,839 | | 3,586 | 10,462,285 | 12,357,285 | 88,583 |
| 3,547 | 7,372,376 | 9,267,376 | 70,277 | | 3,587 | 10,551,111 | 12,446,111 | 89,069 |
| 3,548 | 7,442,873 | 9,337,873 | 70,716 | | 3,588 | 10,640,423 | 12,535,423 | 89,555 |
| 3,549 | 7,513,808 | 9,408,808 | 71,155 | | 3,589 | 10,730,221 | 12,625,221 | 90,041 |
| 3,550 | 7,585,183 | 9,480,183 | 71,594 | | 3,590 | 10,820,505 | 12,715,505 | 90,527 |
| 3,551 | 7,656,995 | 9,551,995 | 72,032 | | 3,591 | 10,911,275 | 12,806,275 | 91,013 |
| 3,552 | 7,729,247 | 9,624,247 | 72,471 | | 3,592 | 11,002,531 | 12,897,531 | 91,499 |
| 3,553 | 7,801,937 | 9,696,937 | 72,910 | | 3,593 | 11,094,273 | 12,989,273 | 91,985 |
| 3,554 | 7,875,067 | 9,770,067 | 73,348 | | 3,594 | 11,186,501 | 13,081,501 | 92,471 |
| 3,555 | 7,948,634 | 9,843,634 | 73,787 | | 3,595 | 11,279,215 | 13,174,215 | 92,957 |
| 3,556 | 8,022,641 | 9,917,641 | 74,226 | | 3,596 | 11,372,415 | 13,267,415 | 93,443 |
| 3,557 | 8,097,086 | 9,992,086 | 74,665 | | 3,597 | 11,466,101 | 13,361,101 | 93,929 |
| 3,558 | 8,171,970 | 10,066,970 | 75,104 | | 3,598 | 11,560,273 | 13,455,273 | 94,415 |
| 3,559 | 8,247,293 | 10,142,293 | 75,542 | | 3,599 | 11,654,931 | 13,549,931 | 94,901 |
| 3,560 | 8,323,055 | 10,218,055 | 75,981 | | 3,600 | 11,750,075 | 13,645,075 | 95,387 |
| 3,561 | 8,399,278 | 10,294,278 | 76,465 | | 3,601 | 11,845,726 | 13,740,726 | 95,914 |
| 3,562 | 8,475,986 | 10,370,986 | 76,950 | | 3,602 | 11,941,903 | 13,836,903 | 96,441 |
| 3,563 | 8,553,177 | 10,448,177 | 77,434 | | 3603 | 12,038,608 | 13,933,608 | 96,968 |
| 3,564 | 8,630,853 | 10,525,853 | 77,918 | | 3,,604 | 12,135,840 | 14,030,840 | 97,495 |
| 3,565 | 8,709,014 | 10,604,014 | 78,402 | | 3,605 | 12,233,599 | 14,128,599 | 98,023 |
| 3,566 | 8,787,658 | 10,682,658 | 78,887 | | 3,606 | 12,331,885 | 14,226,885 | 98,550 |
| 3,567 | 8,866,787 | 10,761,787 | 79,371 | | 3,607 | 12,430,698 | 14,325,698 | 99,077 |
| 3,568 | 8,946,401 | 10,841,401 | 79,855 | | 3,608 | 12,530,038 | 14,425,038 | 99,604 |
| 3,569 | 9,026,498 | 10,921,498 | 80,340 | | 3,609 | 12,629,906 | 14,524,906 | 100,131 |

Table Att. B-1
Lake Powell Elevation to Storage Volume and Surface Area Relationships

| Elevation (feet msl) | Volume Live Capacity (af) | Volume Total Capacity (af) | Surface Area (acres) | | Elevation (feet msl) | Volume Live Capacity (af) | Volume Total Capacity (af) | Surface Area (acres) |
|---|---|---|---|---|---|---|---|---|
| 3,610 | 12,730,300 | 14,625,300 | 100,658 | | 3,650 | 17,215,718 | 19,110,718 | 124,477 |
| 3,611 | 12,831,222 | 14,726,222 | 101,185 | | 3,651 | 17,340,515 | 19,235,515 | 125,119 |
| 3,612 | 12,932,670 | 14,827,670 | 101,712 | | 3,652 | 17,465,955 | 19,360,955 | 125,761 |
| 3,613 | 13,034,646 | 14,929,646 | 102,239 | | 3,653 | 17,592,037 | 19,487,037 | 126,403 |
| 3,614 | 13,137,149 | 15,032,149 | 102,766 | | 3,654 | 17,718,762 | 19,613,762 | 127,046 |
| 3,615 | 13,240,179 | 15,135,179 | 103,294 | | 3,655 | 17,846,128 | 19,741,128 | 127,688 |
| 3,616 | 13,343,736 | 15,238,736 | 103,821 | | 3,656 | 17,974,137 | 19,869,137 | 128,330 |
| 3,617 | 13,447,820 | 15,342,820 | 104,348 | | 3,657 | 18,102,788 | 19,997,788 | 128,972 |
| 3,618 | 13,552,431 | 15,447,431 | 104,875 | | 3,658 | 18,232,082 | 20,127,082 | 129,615 |
| 3,619 | 13,657,570 | 15,552,570 | 105,402 | | 3,659 | 18,362,017 | 20,257,017 | 130,257 |
| 3,620 | 13,763,235 | 15,658,235 | 105,929 | | 3,660 | 18,492,595 | 20,387,595 | 130,899 |
| 3,621 | 13,869,467 | 15,764,467 | 106,535 | | 3,661 | 18,623,863 | 20,518,863 | 131,636 |
| 3,622 | 13,976,306 | 15,871,306 | 107,142 | | 3,662 | 18,755,868 | 20,650,868 | 132,374 |
| 3,623 | 14,083,750 | 15,978,750 | 107,748 | | 3,663 | 18,888,610 | 20,783,610 | 133,111 |
| 3,624 | 14,191,801 | 16,086,801 | 108,354 | | 3,664 | 19,022,090 | 20,917,090 | 133,849 |
| 3,625 | 14,300,458 | 16,195,458 | 108,960 | | 3,665 | 19,156,308 | 21,051,308 | 134,586 |
| 3,626 | 14,409,722 | 16,304,722 | 109,567 | | 3,666 | 19,291,262 | 21,186,262 | 135,323 |
| 3,627 | 14,519,591 | 16,414,591 | 110,173 | | 3,667 | 19,426,954 | 21,321,954 | 136,061 |
| 3,628 | 14,630,067 | 16,525,067 | 110,779 | | 3,668 | 19,563,384 | 21,458,384 | 136,798 |
| 3,629 | 14,741,149 | 16,636,149 | 111,385 | | 3,669 | 19,700,551 | 21,595,551 | 137,536 |
| 3,630 | 14,852,838 | 16,747,838 | 111,992 | | 3,670 | 19,838,455 | 21,733,455 | 138,273 |
| 3,631 | 14,965,132 | 16,860,132 | 112,598 | | 3,671 | 19,977,097 | 21,872,097 | 139,010 |
| 3,632 | 15,078,033 | 16,973,033 | 113,204 | | 3,672 | 20,116,476 | 22,011,476 | 139,748 |
| 3,633 | 15,191,540 | 17,086,540 | 113,810 | | 3,673 | 20,256,592 | 22,151,592 | 140,485 |
| 3,634 | 15,305,654 | 17,200,654 | 114,417 | | 3,674 | 20,397,446 | 22,292,446 | 141,223 |
| 3,635 | 15,420,373 | 17,315,373 | 115,023 | | 3,675 | 20,539,038 | 22,434,038 | 141,960 |
| 3,636 | 15,535,699 | 17,430,699 | 115,629 | | 3,676 | 20,681,366 | 22,576,366 | 142,697 |
| 3,637 | 15,651,631 | 17,546,631 | 116,235 | | 3,677 | 20,824,432 | 22,719,432 | 143,435 |
| 3,638 | 15,768,170 | 17,663,170 | 116,842 | | 3,678 | 20,968,236 | 22,863,236 | 144,172 |
| 3,639 | 15,885,314 | 17,780,314 | 117,448 | | 3,679 | 21,112,777 | 23,007,777 | 144,910 |
| 3,640 | 16,003,065 | 17,898,065 | 118,054 | | 3,680 | 21,258,055 | 23,153,055 | 145,647 |
| 3,641 | 16,121,440 | 18,016,440 | 118,696 | | 3,681 | 21,404,080 | 23,299,080 | 146,404 |
| 3,642 | 16,240,458 | 18,135,458 | 119,339 | | 3,682 | 21,550,863 | 23,445,863 | 147,161 |
| 3,643 | 16,360,117 | 18,255,117 | 119,981 | | 3,683 | 21,698,402 | 23,593,402 | 147,918 |
| 3,644 | 16,480,419 | 18,375,419 | 120,623 | | 3,684 | 21,846,698 | 23,741,698 | 148,674 |
| 3,645 | 16,601,363 | 18,496,363 | 121,265 | | 3,685 | 21,995,751 | 23,890,751 | 149,431 |
| 3,646 | 16,722,950 | 18,617,950 | 121,908 | | 3,686 | 22,145,560 | 24,040,560 | 150,188 |
| 3,647 | 16,845,178 | 18,740,178 | 122,550 | | 3,687 | 22,296,127 | 24,191,127 | 150,945 |
| 3,648 | 16,968,049 | 18,863,049 | 123,192 | | 3,688 | 22,447,450 | 24,342,450 | 151,702 |
| 3,649 | 17,091,562 | 18,986,562 | 123,834 | | 3,689 | 22,599,530 | 24,494,530 | 152,459 |

Table Att. B-1
Lake Powell Elevation to Storage Volume and Surface Area Relationships

| Elevation (feet msl) | Volume Live Capacity (af) | Volume Total Capacity (af) | Surface Area (acres) | | Elevation (feet msl) | Volume Live Capacity (af) | Volume Total Capacity (af) | Surface Area (acres) |
|---|---|---|---|---|---|---|---|---|
| 3,690 | 22,752,368 | 24,647,368 | 153,216 | | 3,701 | 24,483,556 | 26,378,556 | 161,598 |
| 3,691 | 22,905,961 | 24,800,961 | 153,972 | | 3,702 | 24,645,562 | 26,540,562 | 162,413 |
| 3,692 | 23,060,312 | 24,955,312 | 154,729 | | 3,703 | 24,808,381 | 26,703,381 | 163,227 |
| 3,693 | 23,215,420 | 25,110,420 | 155,486 | | 3,704 | 24,972,015 | 26,867,015 | 164,041 |
| 3,694 | 23,371,284 | 25,266,284 | 156,243 | | 3,705 | 25,136,463 | 27,031,463 | 164,855 |
| 3,695 | 23,527,906 | 25,422,906 | 157,000 | | 3,706 | 25,301,726 | 27,196,726 | 165,670 |
| 3,696 | 23,685,284 | 25,580,284 | 157,757 | | 3,707 | 25,467,802 | 27,362,802 | 166,484 |
| 3,697 | 23,843,419 | 25,738,419 | 158,513 | | 3,708 | 25,634,693 | 27,529,693 | 167,298 |
| 3,698 | 24,002,311 | 25,897,311 | 159,270 | | 3,709 | 25,802,398 | 27,697,398 | 168,112 |
| 3,699 | 24,161,959 | 26,056,959 | 160,027 | | 3,710 | 25,970,918 | 27,865,918 | 168,927 |
| 3,700 | 24,322,365 | 26,217,365 | 160,784 | | | | | |

Table Att. B-2
Lake Mead Elevation to Storage Volume and Surface Area Relationships

| Elevation (feet msl) | Volume Live Capacity (af) | Volume Total Capacity (af) | Surface Area (acres) | | Elevation (feet msl) | Volume Live Capacity (af) | Volume Total Capacity (af) | Surface Area (acres) |
|---|---|---|---|---|---|---|---|---|
| 895 | 0 | 2,035,000 | 28,911 | | 937 | 1,413,865 | 3,448,865 | 38,456 |
| 896 | 29,011 | 2,064,011 | 29,119 | | 938 | 1,452,433 | 3,487,433 | 38,682 |
| 897 | 58,234 | 2,093,234 | 29,327 | | 939 | 1,491,228 | 3,526,228 | 38,908 |
| 898 | 87,665 | 2,122,665 | 29,535 | | 940 | 1,530,249 | 3,565,249 | 39,134 |
| 899 | 117,303 | 2,152,303 | 29,742 | | 941 | 1,569,495 | 3,604,495 | 39,357 |
| 900 | 147,153 | 2,182,153 | 29,950 | | 942 | 1,608,964 | 3,643,964 | 39,581 |
| 901 | 177,220 | 2,212,220 | 30,183 | | 943 | 1,648,656 | 3,683,656 | 39,804 |
| 902 | 207,519 | 2,242,519 | 30,416 | | 944 | 1,688,572 | 3,723,572 | 40,027 |
| 903 | 238,052 | 2,273,052 | 30,649 | | 945 | 1,728,711 | 3,763,711 | 40,251 |
| 904 | 268,818 | 2,303,818 | 30,882 | | 946 | 1,769,073 | 3,804,073 | 40,474 |
| 905 | 299,817 | 2,334,817 | 31,116 | | 947 | 1,809,659 | 3,844,659 | 40,697 |
| 906 | 331,049 | 2,366,049 | 31,349 | | 948 | 1,850,468 | 3,885,468 | 40,921 |
| 907 | 362,515 | 2,397,515 | 31,582 | | 949 | 1,891,500 | 3,926,500 | 41,144 |
| 908 | 394,213 | 2,429,213 | 31,815 | | 950 | 1,932,756 | 3,967,756 | 41,367 |
| 909 | 426,145 | 2,461,145 | 32,048 | | 951 | 1,974,256 | 4,009,256 | 41,633 |
| 910 | 458,310 | 2,493,310 | 32,281 | | 952 | 2,016,021 | 4,051,021 | 41,898 |
| 911 | 490,708 | 2,525,708 | 32,515 | | 953 | 2,058,052 | 4,093,052 | 42,164 |
| 912 | 523,339 | 2,558,339 | 32,748 | | 954 | 2,100,348 | 4,135,348 | 42,429 |
| 913 | 556,203 | 2,591,203 | 32,981 | | 955 | 2,142,910 | 4,177,910 | 42,695 |
| 914 | 589,300 | 2,624,300 | 33,214 | | 956 | 2,185,737 | 4,220,737 | 42,960 |
| 915 | 622,631 | 2,657,631 | 33,447 | | 957 | 2,228,830 | 4,263,830 | 43,225 |
| 916 | 656,195 | 2,691,195 | 33,680 | | 958 | 2,272,188 | 4,307,188 | 43,491 |
| 917 | 689,992 | 2,724,992 | 33,913 | | 959 | 2,315,812 | 4,350,812 | 43,756 |
| 918 | 724,022 | 2,759,022 | 34,147 | | 960 | 2,359,701 | 4,394,701 | 44,022 |
| 919 | 758,285 | 2,793,285 | 34,380 | | 961 | 2,403,855 | 4,438,855 | 44,287 |
| 920 | 792,781 | 2,827,781 | 34,613 | | 962 | 2,448,275 | 4,483,275 | 44,553 |
| 921 | 827,507 | 2,862,507 | 34,839 | | 963 | 2,492,960 | 4,527,960 | 44,818 |
| 922 | 862,459 | 2,897,459 | 35,065 | | 964 | 2,537,911 | 4,572,911 | 45,083 |
| 923 | 897,637 | 2,932,637 | 35,291 | | 965 | 2,583,127 | 4,618,127 | 45,349 |
| 924 | 933,041 | 2,968,041 | 35,517 | | 966 | 2,628,609 | 4,663,609 | 45,614 |
| 925 | 968,671 | 3,003,671 | 35,743 | | 967 | 2,674,356 | 4,709,356 | 45,880 |
| 926 | 1,004,527 | 3,039,527 | 35,969 | | 968 | 2,720,369 | 4,755,369 | 46,145 |
| 927 | 1,040,609 | 3,075,609 | 36,195 | | 969 | 2,766,646 | 4,801,646 | 46,411 |
| 928 | 1,076,918 | 3,111,918 | 36,421 | | 970 | 2,813,190 | 4,848,190 | 46,676 |
| 929 | 1,113,452 | 3,148,452 | 36,647 | | 971 | 2,859,995 | 4,894,995 | 46,934 |
| 930 | 1,150,212 | 3,185,212 | 36,873 | | 972 | 2,907,058 | 4,942,058 | 47,192 |
| 931 | 1,187,199 | 3,222,199 | 37,099 | | 973 | 2,954,380 | 4,989,380 | 47,450 |
| 932 | 1,224,411 | 3,259,411 | 37,326 | | 974 | 3,001,959 | 5,036,959 | 47,709 |
| 933 | 1,261,850 | 3,296,850 | 37,552 | | 975 | 3,049,797 | 5,084,797 | 47,967 |
| 934 | 1,299,515 | 3,334,515 | 37,778 | | 976 | 3,097,893 | 5,132,893 | 48,225 |
| 935 | 1,337,405 | 3,372,405 | 38,004 | | 977 | 3,146,247 | 5,181,247 | 48,483 |
| 936 | 1,375,522 | 3,410,522 | 38,230 | | 978 | 3,194,859 | 5,229,859 | 48,741 |

Table Att. B-2
Lake Mead Elevation to Storage Volume and Surface Area Relationships

| Elevation (feet msl) | Volume Live Capacity (af) | Volume Total Capacity (af) | Surface Area (acres) | | Elevation (feet msl) | Volume Live Capacity (af) | Volume Total Capacity (af) | Surface Area (acres) |
|---|---|---|---|---|---|---|---|---|
| 979 | 3,243,729 | 5,278,729 | 48,999 | | 1,021 | 5,552,628 | 7,587,628 | 61,469 |
| 980 | 3,292,857 | 5,327,857 | 49,257 | | 1,022 | 5,614,254 | 7,649,254 | 61,783 |
| 981 | 3,342,244 | 5,377,244 | 49,516 | | 1,023 | 5,676,195 | 7,711,195 | 62,098 |
| 982 | 3,391,888 | 5,426,888 | 49,774 | | 1,024 | 5,738,449 | 7,773,449 | 62,412 |
| 983 | 3,441,791 | 5,476,791 | 50,032 | | 1,025 | 5,801,018 | 7,836,018 | 62,726 |
| 984 | 3,491,952 | 5,526,952 | 50,290 | | 1,026 | 5,863,901 | 7,898,901 | 63,040 |
| 985 | 3,542,371 | 5,577,371 | 50,548 | | 1,027 | 5,927,098 | 7,962,098 | 63,354 |
| 986 | 3,593,048 | 5,628,048 | 50,806 | | 1,028 | 5,990,610 | 8,025,610 | 63,668 |
| 987 | 3,643,983 | 5,678,983 | 51,064 | | 1,029 | 6,054,435 | 8,089,435 | 63,983 |
| 988 | 3,695,177 | 5,730,177 | 51,322 | | 1,030 | 6,118,575 | 8,153,575 | 64,297 |
| 989 | 3,746,628 | 5,781,628 | 51,581 | | 1,031 | 6,183,029 | 8,218,029 | 64,611 |
| 990 | 3,798,338 | 5,833,338 | 51,839 | | 1,032 | 6,247,797 | 8,282,797 | 64,925 |
| 991 | 3,850,325 | 5,885,325 | 52,136 | | 1,033 | 6,312,879 | 8,347,879 | 65,239 |
| 992 | 3,902,611 | 5,937,611 | 52,434 | | 1,034 | 6,378,275 | 8,413,275 | 65,553 |
| 993 | 3,955,194 | 5,990,194 | 52,732 | | 1,035 | 6,443,986 | 8,478,986 | 65,868 |
| 994 | 4,008,074 | 6,043,074 | 53,029 | | 1,036 | 6,510,011 | 8,545,011 | 66,182 |
| 995 | 4,061,252 | 6,096,252 | 53,327 | | 1,037 | 6,576,350 | 8,611,350 | 66,496 |
| 996 | 4,114,728 | 6,149,728 | 53,625 | | 1,038 | 6,643,003 | 8,678,003 | 66,810 |
| 997 | 4,168,502 | 6,203,502 | 53,922 | | 1,039 | 6,709,970 | 8,744,970 | 67,124 |
| 998 | 4,222,573 | 6,257,573 | 54,220 | | 1,040 | 6,777,251 | 8,812,251 | 67,438 |
| 999 | 4,276,942 | 6,311,942 | 54,518 | | 1,041 | 6,844,882 | 8,879,882 | 67,823 |
| 1,000 | 4,331,609 | 6,366,609 | 54,816 | | 1,042 | 6,912,897 | 8,947,897 | 68,208 |
| 1,001 | 4,386,583 | 6,421,583 | 55,133 | | 1,043 | 6,981,297 | 9,016,297 | 68,592 |
| 1,002 | 4,441,874 | 6,476,874 | 55,449 | | 1,044 | 7,050,082 | 9,085,082 | 68,977 |
| 1,003 | 4,497,482 | 6,532,482 | 55,766 | | 1,045 | 7,119,251 | 9,154,251 | 69,361 |
| 1,004 | 4,553,407 | 6,588,407 | 56,083 | | 1,046 | 7,188,804 | 9,223,804 | 69,746 |
| 1,005 | 4,609,649 | 6,644,649 | 56,400 | | 1,047 | 7,258,742 | 9,293,742 | 70,130 |
| 1,006 | 4,666,208 | 6,701,208 | 56,717 | | 1,048 | 7,329,065 | 9,364,065 | 70,515 |
| 1,007 | 4,723,084 | 6,758,084 | 57,034 | | 1,049 | 7,399,772 | 9,434,772 | 70,899 |
| 1,008 | 4,780,277 | 6,815,277 | 57,351 | | 1,050 | 7,470,864 | 9,505,864 | 71,284 |
| 1,009 | 4,837,787 | 6,872,787 | 57,668 | | 1,051 | 7,542,340 | 9,577,340 | 71,669 |
| 1,010 | 4,895,613 | 6,930,613 | 57,985 | | 1,052 | 7,614,201 | 9,649,201 | 72,053 |
| 1,011 | 4,953,757 | 6,988,757 | 58,302 | | 1,053 | 7,686,447 | 9,721,447 | 72,438 |
| 1,012 | 5,012,218 | 7,047,218 | 58,619 | | 1,054 | 7,759,077 | 9,794,077 | 72,822 |
| 1,013 | 5,070,996 | 7,105,996 | 58,936 | | 1,055 | 7,832,091 | 9,867,091 | 73,207 |
| 1,014 | 5,130,090 | 7,165,090 | 59,253 | | 1,056 | 7,905,490 | 9,940,490 | 73,591 |
| 1,015 | 5,189,502 | 7,224,502 | 59,570 | | 1,057 | 7,979,274 | 10,014,274 | 73,976 |
| 1,016 | 5,249,231 | 7,284,231 | 59,887 | | 1,058 | 8,053,442 | 10,088,442 | 74,360 |
| 1,017 | 5,309,277 | 7,344,277 | 60,204 | | 1,059 | 8,127,995 | 10,162,995 | 74,745 |
| 1,018 | 5,369,639 | 7,404,639 | 60,521 | | 1,060 | 8,202,932 | 10,237,932 | 75,130 |
| 1,019 | 5,430,319 | 7,465,319 | 60,838 | | 1,061 | 8,278,239 | 10,313,239 | 75,485 |
| 1,020 | 5,491,315 | 7,526,315 | 61,155 | | 1,062 | 8,353,902 | 10,388,902 | 75,840 |

Table Att. B-2
Lake Mead Elevation to Storage Volume and Surface Area Relationships

| Elevation (feet msl) | Volume Live Capacity (af) | Volume Total Capacity (af) | Surface Area (acres) | | Elevation (feet msl) | Volume Live Capacity (af) | Volume Total Capacity (af) | Surface Area (acres) |
|---|---|---|---|---|---|---|---|---|
| 1,063 | 8,429,920 | 10,464,920 | 76,196 | | 1,105 | 11,943,866 | 13,978,866 | 91,423 |
| 1,064 | 8,506,293 | 10,541,293 | 76,551 | | 1,106 | 12,035,485 | 14,070,485 | 91,814 |
| 1,065 | 8,583,022 | 10,618,022 | 76,906 | | 1,107 | 12,127,494 | 14,162,494 | 92,204 |
| 1,066 | 8,660,106 | 10,695,106 | 77,262 | | 1,108 | 12,219,893 | 14,254,893 | 92,595 |
| 1,067 | 8,737,546 | 10,772,546 | 77,617 | | 1,109 | 12,312,683 | 14,347,683 | 92,985 |
| 1,068 | 8,815,340 | 10,850,340 | 77,972 | | 1,110 | 12,405,864 | 14,440,864 | 93,376 |
| 1,069 | 8,893,490 | 10,928,490 | 78,328 | | 1,111 | 12,499,435 | 14,534,435 | 93,766 |
| 1,070 | 8,971,996 | 11,006,996 | 78,683 | | 1,112 | 12,593,397 | 14,628,397 | 94,157 |
| 1,071 | 9,050,857 | 11,085,857 | 79,038 | | 1,113 | 12,687,749 | 14,722,749 | 94,548 |
| 1,072 | 9,130,073 | 11,165,073 | 79,394 | | 1,114 | 12,782,492 | 14,817,492 | 94,938 |
| 1,073 | 9,209,644 | 11,244,644 | 79,749 | | 1,115 | 12,877,626 | 14,912,626 | 95,329 |
| 1,074 | 9,289,571 | 11,324,571 | 80,105 | | 1,116 | 12,973,149 | 15,008,149 | 95,719 |
| 1,075 | 9,369,853 | 11,404,853 | 80,460 | | 1,117 | 13,069,064 | 15,104,064 | 96,110 |
| 1,076 | 9,450,491 | 11,485,491 | 80,815 | | 1,118 | 13,165,369 | 15,200,369 | 96,500 |
| 1,077 | 9,531,484 | 11,566,484 | 81,171 | | 1,119 | 13,262,064 | 15,297,064 | 96,891 |
| 1,078 | 9,612,832 | 11,647,832 | 81,526 | | 1,120 | 13,359,150 | 15,394,150 | 97,281 |
| 1,079 | 9,694,536 | 11,729,536 | 81,881 | | 1,121 | 13,456,647 | 15,491,647 | 97,713 |
| 1,080 | 9,776,595 | 11,811,595 | 82,237 | | 1,122 | 13,554,576 | 15,589,576 | 98,145 |
| 1,081 | 9,859,002 | 11,894,002 | 82,578 | | 1,123 | 13,652,937 | 15,687,937 | 98,577 |
| 1,082 | 9,941,751 | 11,976,751 | 82,919 | | 1,124 | 13,751,730 | 15,786,730 | 99,008 |
| 1,083 | 10,024,841 | 12,059,841 | 83,261 | | 1,125 | 13,850,954 | 15,885,954 | 99,440 |
| 1,084 | 10,108,272 | 12,143,272 | 83,602 | | 1,126 | 13,950,610 | 15,985,610 | 99,872 |
| 1,085 | 10,192,045 | 12,227,045 | 83,943 | | 1,127 | 14,050,698 | 16,085,698 | 100,304 |
| 1,086 | 10,276,159 | 12,311,159 | 84,285 | | 1,128 | 14,151,218 | 16,186,218 | 100,736 |
| 1,087 | 10,360,614 | 12,395,614 | 84,626 | | 1,129 | 14,252,169 | 16,287,169 | 101,167 |
| 1,088 | 10,445,411 | 12,480,411 | 84,967 | | 1,130 | 14,353,553 | 16,388,553 | 101,599 |
| 1,089 | 10,530,549 | 12,565,549 | 85,309 | | 1,131 | 14,455,368 | 16,490,368 | 102,031 |
| 1,090 | 10,616,028 | 12,651,028 | 85,650 | | 1,132 | 14,557,615 | 16,592,615 | 102,463 |
| 1,091 | 10,701,869 | 12,736,869 | 86,032 | | 1,133 | 14,660,293 | 16,695,293 | 102,895 |
| 1,092 | 10,788,092 | 12,823,092 | 86,414 | | 1,134 | 14,763,404 | 16,798,404 | 103,326 |
| 1,093 | 10,874,698 | 12,909,698 | 86,796 | | 1,135 | 14,866,946 | 16,901,946 | 103,758 |
| 1,094 | 10,961,685 | 12,996,685 | 87,178 | | 1,136 | 14,970,920 | 17,005,920 | 104,190 |
| 1,095 | 11,049,054 | 13,084,054 | 87,560 | | 1,137 | 15,075,326 | 17,110,326 | 104,622 |
| 1,096 | 11,136,805 | 13,171,805 | 87,942 | | 1,138 | 15,180,164 | 17,215,164 | 105,054 |
| 1,097 | 11,224,939 | 13,259,939 | 88,324 | | 1,139 | 15,285,433 | 17,320,433 | 105,485 |
| 1,098 | 11,313,454 | 13,348,454 | 88,706 | | 1,140 | 15,391,135 | 17,426,135 | 105,917 |
| 1,099 | 11,402,352 | 13,437,352 | 89,089 | | 1,141 | 15,497,372 | 17,532,372 | 106,558 |
| 1,100 | 11,491,631 | 13,526,631 | 89,471 | | 1,142 | 15,604,251 | 17,639,251 | 107,199 |
| 1,101 | 11,581,297 | 13,616,297 | 89,861 | | 1,143 | 15,711,770 | 17,746,770 | 107,840 |
| 1,102 | 11,671,354 | 13,706,354 | 90,252 | | 1,144 | 15,819,930 | 17,854,930 | 108,480 |
| 1,103 | 11,761,801 | 13,796,801 | 90,642 | | 1,145 | 15,928,731 | 17,963,731 | 109,121 |
| 1,104 | 11,852,638 | 13,887,638 | 91,033 | | 1,146 | 16,038,172 | 18,073,172 | 109,762 |

Table Att. B-2
Lake Mead Elevation to Storage Volume and Surface Area Relationships

| Elevation (feet msl) | Volume Live Capacity (af) | Volume Total Capacity (af) | Surface Area (acres) | | Elevation (feet msl) | Volume Live Capacity (af) | Volume Total Capacity (af) | Surface Area (acres) |
|---|---|---|---|---|---|---|---|---|
| 1,147 | 16,148,255 | 18,183,255 | 110,403 | | 1,189 | 21,364,868 | 23,399,868 | 138,210 |
| 1,148 | 16,258,978 | 18,293,978 | 111,044 | | 1,190 | 21,503,408 | 23,538,408 | 138,870 |
| 1,149 | 16,370,342 | 18,405,342 | 111,684 | | 1,191 | 21,642,579 | 23,677,579 | 139,472 |
| 1,150 | 16,482,347 | 18,517,347 | 112,325 | | 1,192 | 21,782,352 | 23,817,352 | 140,074 |
| 1,151 | 16,594,992 | 18,629,992 | 112,966 | | 1,193 | 21,922,727 | 23,957,727 | 140,677 |
| 1,152 | 16,708,279 | 18,743,279 | 113,607 | | 1,194 | 22,063,705 | 24,098,705 | 141,279 |
| 1,153 | 16,822,206 | 18,857,206 | 114,248 | | 1,195 | 22,205,285 | 24,240,285 | 141,881 |
| 1,154 | 16,936,774 | 18,971,774 | 114,888 | | 1,196 | 22,347,468 | 24,382,468 | 142,483 |
| 1,155 | 17,051,983 | 19,086,983 | 115,529 | | 1,197 | 22,490,252 | 24,525,252 | 143,086 |
| 1,156 | 17,167,833 | 19,202,833 | 116,170 | | 1,198 | 22,633,639 | 24,668,639 | 143,688 |
| 1,157 | 17,284,323 | 19,319,323 | 116,811 | | 1,199 | 22,777,628 | 24,812,628 | 144,290 |
| 1,158 | 17,401,454 | 19,436,454 | 117,452 | | 1,200 | 22,922,220 | 24,957,220 | 144,893 |
| 1,159 | 17,519,226 | 19,554,226 | 118,092 | | 1,201 | 23,067,429 | 25,102,429 | 145,526 |
| 1,160 | 17,637,639 | 19,672,639 | 118,733 | | 1,202 | 23,213,271 | 25,248,271 | 146,159 |
| 1,161 | 17,756,711 | 19,791,711 | 119,410 | | 1,203 | 23,359,746 | 25,394,746 | 146,792 |
| 1,162 | 17,876,460 | 19,911,460 | 120,087 | | 1,204 | 23,506,855 | 25,541,855 | 147,425 |
| 1,163 | 17,996,885 | 20,031,885 | 120,764 | | 1,205 | 23,654,596 | 25,689,596 | 148,058 |
| 1,164 | 18,117,988 | 20,152,988 | 121,441 | | 1,206 | 23,802,971 | 25,837,971 | 148,691 |
| 1,165 | 18,239,767 | 20,274,767 | 122,118 | | 1,207 | 23,951,978 | 25,986,978 | 149,324 |
| 1,166 | 18,362,224 | 20,397,224 | 122,795 | | 1,208 | 24,101,619 | 26,136,619 | 149,957 |
| 1,167 | 18,485,357 | 20,520,357 | 123,472 | | 1,209 | 24,251,893 | 26,286,893 | 150,590 |
| 1,168 | 18,609,168 | 20,644,168 | 124,149 | | 1,210 | 24,402,800 | 26,437,800 | 151,224 |
| 1,169 | 18,733,655 | 20,768,655 | 124,826 | | 1,211 | 24,554,316 | 26,589,316 | 151,808 |
| 1,170 | 18,858,820 | 20,893,820 | 125,503 | | 1,212 | 24,706,417 | 26,741,417 | 152,393 |
| 1,171 | 18,984,661 | 21,019,661 | 126,180 | | 1,213 | 24,859,103 | 26,894,103 | 152,978 |
| 1,172 | 19,111,179 | 21,146,179 | 126,857 | | 1,214 | 25,012,373 | 27,047,373 | 153,563 |
| 1,173 | 19,238,375 | 21,273,375 | 127,534 | | 1,215 | 25,166,229 | 27,201,229 | 154,148 |
| 1,174 | 19,366,247 | 21,401,247 | 128,211 | | 1,216 | 25,320,669 | 27,355,669 | 154,733 |
| 1,175 | 19,494,796 | 21,529,796 | 128,888 | | 1,217 | 25,475,695 | 27,510,695 | 155,318 |
| 1,176 | 19,624,022 | 21,659,022 | 129,565 | | 1,218 | 25,631,305 | 27,666,305 | 155,903 |
| 1,177 | 19,753,925 | 21,788,925 | 130,242 | | 1,219 | 25,787,500 | 27,822,500 | 156,488 |
| 1,178 | 19,884,505 | 21,919,505 | 130,919 | | 1,220 | 25,944,281 | 27,979,281 | 157,073 |
| 1,179 | 20,015,762 | 22,050,762 | 131,595 | | 1,221 | 26,101,666 | 28,136,666 | 157,697 |
| 1,180 | 20,147,696 | 22,182,696 | 132,272 | | 1,222 | 26,259,675 | 28,294,675 | 158,322 |
| 1,181 | 20,280,298 | 22,315,298 | 132,932 | | 1,223 | 26,418,310 | 28,453,310 | 158,947 |
| 1,182 | 20,413,560 | 22,448,560 | 133,592 | | 1,224 | 26,577,569 | 28,612,569 | 159,572 |
| 1,183 | 20,547,482 | 22,582,482 | 134,252 | | 1,225 | 26,737,453 | 28,772,453 | 160,196 |
| 1,184 | 20,682,064 | 22,717,064 | 134,911 | | 1,226 | 26,897,962 | 28,932,962 | 160,821 |
| 1,185 | 20,817,305 | 22,852,305 | 135,571 | | 1,227 | 27,059,095 | 29,094,095 | 161,446 |
| 1,186 | 20,953,206 | 22,988,206 | 136,231 | | 1,228 | 27,220,854 | 29,255,854 | 162,071 |
| 1,187 | 21,089,767 | 23,124,767 | 136,891 | | 1,229 | 27,383,237 | 29,418,237 | 162,695 |
| 1,188 | 21,226,987 | 23,261,987 | 137,550 | | | | | |

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