ATTACHMENT J

Detailed Modeling Documentation

The river system operation analysis for this FEIS was conducted with Reclamation's Colorado River Simulation System model implemented in the RiverWare modeling system. This attachment contains detailed documentation of the modeling process.

Detailed Modeling Documentation

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

BACKGROUND

Long-term policy and planning studies on the Colorado River have typically used model results from the Colorado River Simulation System (CRSS), a Fortran-based modeling system, developed in the 1980's. CRSS originally ran on a Cyber mainframe computer, but was ported to run on both personal computers and Unix Workstations in 1994. CRSS modeled twelve major reservoirs and some 115 diversion points throughout the Upper and Lower basins on a monthly time step. A major drawback of 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 1990's, Reclamation developed an annual time step model, CRSSez (BOR, 1998). CRSSez primarily models the operation of Lakes Powell and Mead, representing the reservoirs above Powell as one aggregate reservoir, and the effect of reservoirs below Mead as part of the water demand necessary from Mead. CRSSez was used in the Interim Surplus Criteria EIS process to facilitate the development of possible alternatives to be analyzed.

Also 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 the Upper and Lower Colorado Regions for both planning and monthly 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, 1999). The user expresses and prioritizes the rules through the RiverWare graphical user interface, and RiverWare then interprets the rules when the model is run. Multiple rule sets can be run with 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 runs were made between the original CRSS and the new model and rule set, with typical differences of less than 0.5% (BOR, 1996).

The second phase of the program to replace CRSS consists of examining the rules extracted from CRSS and developing new rule sets that reflect current operational policy as well as to investigate and improve, 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 this phase is on going.

DESCRIPTION OF THE MODEL

As previously mentioned, the features represented in the model are identical to the original CRSS model. In summary, twelve reservoirs are modeled (Fontenelle, Flaming Gorge, Taylor Park, Blue Mesa, Morrow Point, Crystal, Navajo, Starvation, Powell, Mead, Mohave, Havasu) and approximately 115 diversions are modeled (demands and return flows) throughout the basin. The Lower and Upper Basin diversion and depletion schedules used in this EIS are documented in Section 3.4.5 and Attachments G and J respectively. 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 1906-1990.

For the analysis conducted for this EIS, only the operation of Lake Powell was updated to reflect current operational policy in the Upper Basin. Operation of the other reservoirs in the Upper Basin essentially followed the operation in the original CRSS. Operation of Lakes Mead, Mohave, and Havasu also followed that of the original CRSS, with the exception of the surplus and shortage rules as described below.

RESERVOIRS ABOVE LAKE POWELL

The reservoirs above 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 run 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 cfs) as specified in the following table:

Reservoir	Min Release	Max Release
Fontenelle	500	18700
Flaming Gorge	800	4900
Starvation	100	5000
Taylor Park	50	5000
Blue Mesa	270	5000
Morrow Point	300	5000
Crystal	300	4200
Navajo	300	5900

For Flaming Gorge, Blue Mesa, and Navajo, the target storage is computed by using an inflow forecast for the spring runoff season (January through July), again to mimic the imperfect forecasts seen in actual operations. The forecasted inflow (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:

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 each reservoir are (1000 af):

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 for any gains or losses above the reservoir:

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

LAKE POWELL OPERATION

As previously stated, the operation of Lake Powell was modified to reflect current operating polices. In the original CRSS rules, Lake Powell was operated on a rule curve that was *not* adjusted for an inflow forecast. Two other higher priority rules ensured that the minimum objective release of 8.23 million afy was met and that equalization of Lakes Powell and Mead was accomplished when necessary.

The rule curve operation of Lake Powell was replaced by a new rule that better represents current operational practices. This new rule consists of a forecast-driven, spring runoff operation (January through July) that attempts to fill the reservoir to a July target storage and a fall operation (August through December) that attempts to draw down the reservoir to a December target storage. For this EIS, the July and December targets were 23.822 maf (500 kaf of space) and 21.900 maf (2.422 kaf of space) respectively. In addition, a rule was added to simulate the occurrence of Beach Habitat Building Flows (BHBF's or "spike" flows). The minimum objective release and equalization rules were kept essentially the same as in the original CRSS rules. Release constraints that reflect the 1996 Record of Decision on the Operation of Glen Canyon Dam were also added to the Lake Powell rule set.

LAKE POWELL INFLOW FORECAST

Since the original CRSS rules computed an inflow forecast for Lake Powell and adjusted it for use by the flood control operation at Lake Mead, the same forecasting algorithm could be applied to the new operation of Lake Powell. The unregulated Lake Powell inflow forecast from the current month through July is computed as:

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.

As detailed in the original CRSS overview document (BOR, 1985), analysis of these data revealed two strongly established patterns: (1) high runoff years are under-forecast, and low runoff years are over-forecast; (2) the error in the current month's seasonal forecast is strongly correlated with the error in the preceding month's forecast. 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 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 X_i.
- $E_{(i-1)}$ = 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
- d_i = standard error of estimate for regression equation for month "i."

The following table summarizes the regression equation coefficients for each month:

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.

SPRING RUNOFF OPERATION (JANUARY THROUGH JULY)

To accomplish the spring operation, the unregulated forecast is first adjusted to account for potential reservoir regulation above 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. Using the regulated forecasted inflow, the total volume of water necessary to release from the current month through July is computed as:

total volume to release = previous storage – July target storage
+ forecasted 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 as follows:

Spring Season	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 spring operation, however, 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 in the season during high forecast years. Lake Powell's spring operational release is further constrained in each month to be within a minimum and maximum range (currently set to 6500 and 25000 cfs respectively).

FALL OPERATION (AUGUST THROUGH DECEMBER)

Conceptually, the computation for the fall operation is identical to that done for the spring operation. 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, where the space is the target storage in December for each reservoir minus the previous month's storage. User-supplied weights are also used to compute the current month release from the total volume to release in the fall. The weights and resulting fractions are as follows:

Fall Season	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 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 a storage at Lake Powell less than 23.822 maf. Powell's fall operational release is further constrained in each month to be within a minimum and maximum range (currently set to 6500 and 25000 cfs respectively).

MINIMUM OBJECTIVE RELEASE

A higher priority rule ensures that the previously described 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 as follows:

Month	Release	Fraction
October	600	0.073
November	600	0.079
December	700	0.100
January	800	0.126
February	700	0.127
March	600	0.124
April	600	0.142
May	600	0.165
June	700	0.231
July	800	0.343
August	900	0.588
September	630	1.000

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

EQUALIZATION OF LAKES POWELL AND MEAD

The equalization of storage between Lakes Powell and 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 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) requirement, and (2), if the projected end-of-water-year (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 previous month's storage for Flaming Gorge, Blue Mesa, and Navajo. That storage is then compared to the computed value of 602(a) storage, described below to see if the 602(a) requirement is met each month. The method of estimating the EOWY storage is described below.

The release for equalization is computed by taking half of the difference between the predicted EOWY contents of Lake Powell and Lake Mead and dividing by the number of months remaining through September. Evaporation and bank storage losses at Lakes Powell and Mead are included in the calculation, resulting in an iterative procedure to arrive at the computed equalization release. The iteration stops when the forecasted EOWY contents of Lake Powell and Lake Mead are within a user-specified tolerance. That tolerance is currently set to 25000 acre-feet.

The computed equalization release for each month is constrained in three ways. If the additional release due to equalization would cause the total Upper Basin storage to drop below the 602(a) requirement, then the amount of the equalization release is reduced to prevent this from happening. Likewise, the equalization release is reduced if it would cause Lake Mead contents to exceed its exclusive flood control space. Finally, the equalization release is constrained to be less than or equal to the maximum power plant capacity at Lake Powell (currently set to 33,100 cfs).

602(a) STORAGE REQUIREMENT

As stated in the CRSS overview document (BOR, 1985), "602(a) storage 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". The current implementation of that storage requirement duplicates the original CRSS calculation. It computes the storage 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 1953-1964, 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 ported from the Cyber mainframe in 1994.

PREDICTING END-OF-WATER-YEAR (EOWY) CONTENTS OF LAKES POWELL AND MEAD

Lake Powell EOWY content is predicted each month by taking 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 spring operation (through July) and the fall operation for August and September. The estimated evaporation and bank storage losses are based on an initial estimate of the EOWY content.

Similarly, the Lake Mead EOWY content is predicted each month by taking the previous month's content, adding the estimated Powell release, subtracting the estimated Mead release, adding the average gain between Powell and 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 Mead and the reservoir regulation requirements (including evaporation losses) for Lakes Mohave and Havasu minus the gains below Mead.

BEACH /HABITAT BUILDING FLOWS (BHBF'S)

Under the current rule that implements BHBF's, 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)
- in January through July, if the current month's 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 Powell would have had to spill in that month anyway, the total outflow from 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 Powell was not going to spill in that month, then the total outflow from Powell is increased (i.e., the volume for the BHBF is taken from 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 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.

LAKE MEAD OPERATION

Lake Mead is operated primarily to meet downstream demand, including downstream depletions (both U.S. 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 (for the case of surplus or shortage in the Lower Basin). The reservoir regulation requirements for Lakes Mohave and Havasu include water necessary to meet their storage targets and evaporation losses for each month. The operation rule computes the release necessary from Lake Mead to meet that total downstream demand minus gains below Mead. This release may be increased, however, based on flood control procedures.

MEAD 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 were based on the Field Working Agreement between Reclamation and the Army Corps of Engineers (ACOE, 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 1219.61. The second procedure is used during the spring runoff forecast season (January through July). The objective during this period is to route the maximum forecasted inflow through the reservoir system using specific rates of Hoover Dam discharge, assuming that the lake will fill (to elevation 1219.61) 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.

EXCLUSIVE FLOOD CONTROL SPACE REQUIREMENT

As previously noted, this requirement states that space in Lake Mead must be a minimum of 1.5 maf 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.

SPRING RUNOFF SEASON (JANUARY THROUGH JULY)

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% non-exceedance). The rule first computes the inflow forecast to Lake Mead by taking the Lake Powell forecast previously described and adds the long-term, average natural tributary inflows between Lakes Powell and Mead. The maximum forecast is then estimated by adding an additional volume (the "forecast error term") to that inflow forecast. The forecast error term is given in the following table, taken from the original CRSS data:

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 is determined. Certain release levels are specified and are given in the following table:

Release Level	Release (cfs)	Description
1	19000	Parker powerplant capacity
2	28000	Davis powerplant capacity
3	35000	Hoover powerplant capacity (in 1987)
4	40000	Approx. max. flow non-damaging to streambed
5	73000	Hoover controlled discharge capacity

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

> release needed for the current month = maximum forecasted inflow - current storage space in Lake Powell (below 3700 feet) – current storage space in Lake Mead (below 1229 feet) + 1.5 maf (exclusive space) - evaporation and bank storage losses from Lakes Powell and Mead - Southern Nevada depletion – future volume of water released (assuming a release level from the table 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.

SPACE BUILDING (AUGUST THROUGH DECEMBER)

The flood control policy states the flood control storage space in Lake Mead (storage below elevation 1229 feet) required at the beginning of each month from August through January:

Date	Space Required (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 active storage. Certain upstream reservoirs are specified with a maximum creditable space for each:

Reservoir	Max. 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.

LAKE MOHAVE AND LAKE HAVASU OPERATION

Lakes Mohave and Havasu are operated to meet a user-specified target storage at the end of each month. These storage targets are given in the following table:

Month	Mohave Target Storage (kaf)	Havasu Target Storage (kaf)
January	1644.0	539.1
February	1698.7	539.1
March	1698.7	557.4
April	1698.7	593.6
May	1753.9	611.4
June	1666.0	611.4
July	1543.0	580.0
August	1417.0	561.1
September	1371.1	557.4
October	1371.1	548.2
November	1478.0	542.7
December	1585.0	539.1

LOWER BASIN SHORTAGE STRATEGIES

As discussed in Section 3.3.3.4, although there are no established shortage criteria for the Lower Basin, shortage rules were developed and used in the model simulation to address concerns related to low Lake Mead elevations. For this DEIS, a “two-level” shortage protection strategy was used.

In Level 1 shortage, 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. If Lake Mead’s elevation at the beginning of the year is less than the trigger elevation, a Level 1 shortage is declared and certain Lower Basin depletions are reduced. The shortage remains in effect for that calendar year.

For this DEIS, Level 1 protection of elevation 1083 feet (minimum power pool) and Level 1 protection of elevation 1050 feet (minimum water level for operation of Southern Nevada's upper diversion intake) were studied separately. Trigger elevations were input to protect each elevation with an 80% probability; however, actual model runs showed that the protection was less (approximately 74%). As discussed in Section 3.3.4.1, these trigger elevations will be adjusted for the Final EIS to ensure an 80% protection probability.

Under Level 1 shortage, the Central Arizona Project (CAP) depletion is set to a given amount (1.0 maf for this DEIS) and Southern Nevada Water Authority (SNWA) is reduced by 4% of the total reduction as given by:

$$SNWS_{short} = SNWS_{norm} – (0.04*(CAP_{norm}-CAP_{short})/0.96)$$

where the subscripts denote the normal and shortage depletion amounts. Metropolitan Water District (MWD) and other water users (including Mexico) do not take a Level 1 shortage.

Under Level 2 shortages, further cuts are imposed to keep Lake Mead above elevation 1000 feet (the minimum water level for operation of SNWA's lower diversion intake). At the beginning of each year, the rule estimates the end-of-water-year (EOWY) Lake Mead elevation (using Level 1 shortage schedules and normal schedules for other users). If the EOWY elevation is below 1000 feet, CAP and SNWA are cut further to keep Lake Mead above 1000 feet. If CAP delivery is reduced to zero, MWD and Mexico have shortages imposed, again in an amount necessary to keep the reservoir above 1000 feet. Shortages to Mexico consist of shorting Mexico proportionately to the total shortages imposed on United States (U.S.) users:

$$Mex_{short} = Mex_{norm} * (U.S._{shortage}/U.S._{norm})$$

For this DEIS, however, Level 2 shortages were never severe enough to impose shortages on MWD and Mexico.

LOWER BASIN SURPLUS STRATEGIES

As discussed in Chapter 2, several surplus strategies were proposed for inclusion in this DEIS. Of the five alternatives that were developed and analyzed in detail (the No Action Alternative and the four action alternatives), four distinct strategies were used: the Flood Control Strategy, the R strategy, the P strategy, and the Multi-tiered Trigger strategy.

FLOOD CONTROL STRATEGY

Under the Flood Control strategy, a surplus condition is based on the flood control procedures previously described for Lake Mead. For each month, the rule calculates the release necessary for flood control and declares a surplus for the remainder of the calendar year if that release is greater than the release necessary to meet normal downstream demand. Monthly "full" surplus schedules are then set for the remainder of the year, where the monthly surplus schedules are determined by applying monthly percentages to the annual "full" surplus values given in Attachment G (Table G-4). Mexico receives up to an additional 200 kaf only under a flood control surplus. Under most cases, the flood control release is sufficient to meet the increased downstream demand; however, if that is not the case, the rule increases the release so that the surplus demands are met.

All alternatives analyzed in this EIS used the Flood Control surplus strategy, in addition to any other strategies.

R STRATEGY

Under the R surplus strategy, a surplus condition is based on the system space requirement at the beginning of each year. Based on an assumed runoff, Upper and Lower Basin depletion schedules, and Lake Powell and Lake Mead contents 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 and full surplus schedules are met for the year. It should be noted that variations of the R strategies include a "volume limited" surplus, where just the computed surplus volume is distributed to certain Lower Basin users (i.e., a full surplus is not assumed).

The assumed runoff corresponds to a particular percentile historical runoff. For example, the 75R strategy assumes a runoff corresponding to the 75^{th} percentile (75% of the historical values are less than that value, or approximately 18.1 maf of natural inflow into Lake Powell).

Based on the original CRSS implementation, the surplus volume is computed by:

SurVol = (PowellStorage + MeadStorage – maxStorage) x (1.0 + aveBankStorCoeff) + runoff – UBdemand – Lbdemand

Where:

PowellStorage = Lake Powell content at the beginning of the year
MeadStorage = Lake Mead content at the beginning of the year
maxStorage = maximum combined storage at Lakes Powell and 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 Powell (live capacity of Lakes Powell and Mead - 0.7 x 5.35 maf = 47.96 maf)
aveBankStorageCoeff = 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 equalization, 560 kaf)
LBdemand = sum of the depletions below Powell + the evaporation losses in the Lower Basin (average loss of 900 kaf at Mead and computed for Lakes Mohave and Havasu, based on the target storage) – average gains between Powell and Mead (801 kaf) – average gains below Mead (427 maf)

P STRATEGY

Under the Protection or P strategy, a surplus is determined if there is sufficient water in Lake Mead to meet normal Lower Basin depletions (7.5 maf), while avoiding the likelihood of a future shortage determination. Analogous to Level 1 shortages, the surplus 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 the shortage line with a given degree of confidence. If the Lake Mead elevation is greater than the trigger elevation, a full surplus is declared for that calendar year.

For this DEIS, an 80% confidence of avoiding future Level 1 shortages was used to compute the trigger elevations (Section 2.3.5).

MULTI-TIERED TRIGGER STRATEGY

Under the multi-tiered trigger strategies, various amounts of surplus water are made available, depending upon Lake Mead's elevation at the beginning of each calendar year. Both the Six States Alternative and the California Alternative use this strategy. The trigger elevations used in this DEIS for each alternative are discussed in Sections 2.3.3 and 2.3.4 respectively. The surplus depletion schedules used for each alternative are detailed in another attachment.

REFERENCES

Army Corps of Engineers (ACOE), 1982, "Water Control Manual for Flood Control: Hoover Dam and Lake Mead, Colorado River", Los Angeles, California

Bureau of Reclamation (BOR), 1985, "Colorado River Simulation System: System Overview", Denver, Colorado

Bureau of Reclamation (BOR), 1998, "CRSSez: Annual Colorado River System Simulation Model, Overview and Users Manual", Boulder City, Nevada

Bureau of Reclamation (BOR), 1996, "Replacement of the Colorado River Simulation System", Draft Report, Boulder City, Nevada

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

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

Zagona, E., Shane, R., Fulp, T., Magee, T., and Goranflo, M., 1999, "RiverWare: A Generalized Tool for Complex Reservoir System Modeling", paper (No. 99301) submitted to the Journal of the American Water Resources Association