Colorado River Risk Study: Phase I Summary Report

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Submitted to the Colorado River District and Project Participants

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I. Introduction

A. Background

The Colorado River Basin is in the midst of a drought that began in 2000 and continues today. Average naturalized flows at Lee Ferry during this period are approximately 12.5 maf (million acre-feet), or 4.0 maf annually less than would be needed to meet the full compact allotments of the seven basin states and deliveries to Mexico. Recent droughts have significantly reduced storage levels in Lake Powell. If these droughts were to repeat themselves today, the viability of Lake Powell would be threatened (Figure 1). Drought Contingency Plans (DCP) are being developed for both the Upper and Lower Basins (See Hydros 2015 report "Summary Report on Contingency Planning in the Colorado River Basin"). While those plans, if implemented, would reduce the risk of a compact deficit or critically low storage levels at Lake Powell, they do not completely eliminate the risk for the Upper Basin States.

Concurrent with the DCP efforts, Colorado completed its Water Plan, which lays the foundation for a secure water supply for the State. Point #4 of the Plan's Seven Point Framework is to take actions that minimize the risk of a Colorado River Compact curtailment. That objective, plus concerns voiced by the Colorado River Basin Round Tables (BRTs) in a joint meeting in December 2014, provided the catalyst for this work.

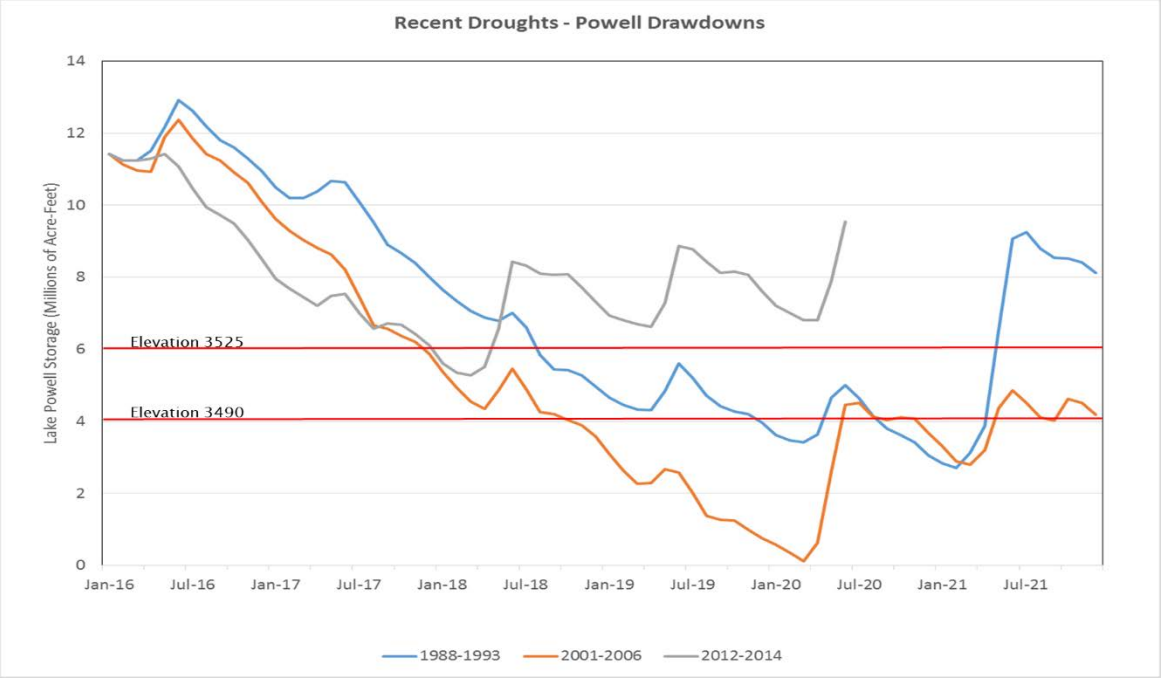

Figure 1. Past Lake Powell drawdowns superimposed on current conditions. A repeat of any of the last three drought events and subsequent drawdown of Powell would threaten the Upper Basin's ability to meet its obligations under the 2007 Interim Guidelines. The Upper Basin States and Reclamation have designed a Contingency Plan to keep Powell's elevation above the 3525' threshold.

B. Project Phasing

The project has been structured as a multi-phase process. Phase I, documented herein, lays the groundwork for evaluating any number of different state-wide or sub-basin specific scenarios dealing with questions of curtailment, demand management, water banking, and risk sensitivity to model variables such as demands and hydrology. The analyses thus far have relied entirely on modeling performed with the Colorado River Simulation System (CRSS) tool. CRSS is Reclamation's "big river" model that it uses for Basin-wide planning studies. Later phases of this project will build upon the work from this initial phase, and will likely include incorporation of StateMod to address water rights-specific questions that are not well simulated in CRSS.

Given the DCP processes in both basins, the key questions addressed by Phase I of the study are:

1. What are magnitude and duration of Powell shortages below elevation 3525'?
2. How much of the above shortages can be met by contributions from Drought Operations of CRSP reservoirs?
3. How much consumptive use reduction ("demand management") would be needed by Upper Basin states - AFTER use of stored CRSP water - in order to maintain Powell pool elevations?

C. Basin Roundtable Participation and Communications

The CWCB (Through the four west slope BRTs), Colorado River District, and Southwestern District contributed funding to Phase I. Platte, Metro, and Arkansas BRT members were invited to participated in numerous webinars and meetings and have provided valuable feedback throughout the process. Three different webinar series were held during the summer of 2016, providing participants numerous opportunities to understand the modeling process and provide feedback on assumptions and results. Upon completion of the model scenario analysis, in-person presentations were made to each of the west slope BRTs, a group of Front Range participants, and technical committees from the Colorado and Southwestern Districts.

II. Colorado River Operations under the Interim Guidelines

The Record of Decision on the Colorado River Interim Guidelines for Lower Basin Shortages and the Coordinated Operations for Lake Powell and Lake Mead (The "Interim Guidelines"; Secretary of the Interior, 2007) is the guiding document for "Big River" Colorado River operations through the end of 2026. It dictates under what conditions and in what quantity water stored in Lake Powell will be released to Lake Mead. It also includes criteria for the determination of shortages in the Lower Basin States, and the apportionments to those states in shortage years, as well as criteria for the establishment of Intentionally Created Surplus (ICS) accounts at Lake Mead to encourage water conservation as an additional hedge against prolonged drought.

The operation of Lakes Powell and Mead as described in the Interim Guidelines, as well as the shortage criteria and ICS rules, are implemented within the CRSS model using its embedded rule policy language. Unless otherwise noted, model simulations assume that the Interim Guidelines DO NOT expire in 2026. In CRSS, this is implemented through continuation of the operational policies as described in the Guidelines, including an extrapolation of the upper "equalization curve" to account for ongoing growth in the Upper Basin states. The extrapolation of these operational policies is identical to those used in extending the Interim Guidelines rules in the Basin Study.

Operation of all other reservoirs represented in CRSS are as provided by Reclamation, except in the implementation of Extended Operations rules for the Navajo, Aspinall, and Flaming Gorge Units as described below.

III. Modeling Assumptions

As a starting point for this modeling exercise, we utilize the same CRSS models that have been used for the Drought Contingency Planning process by the upper and lower basins. Unless otherwise explicitly noted below, the model assumptions used herein are the same as those used in the Hydros report on Contingency Planning (Appendix F). The most significant changes from the DCP model assumptions used previously include an updated set of conservation assumptions for the lower basin DCP, a new demand schedule for the upper basin states, and updating of initial conditions to reflect the January 2016 forecast reservoir conditions from Reclamation's August 2015 24-month study model runs. Model results analysis, unless otherwise noted, is for the simulation period 2016-2036.

A. Upper Basin DCP

The model utilizes the most recent ruleset from Reclamation that reflects the proposed operating policy of the CRSP reservoirs under drought operations. These rules provide for drought operations at Flaming Gorge, Aspinall, and Navajo units as triggered by the January 1 Lake Powell 3525 elevation threshold.

There is no triggered demand management in these scenarios, which is a departure from the fixed-volume approach used in the original DCP runs for the UCRC. One objective of this study is to quantify the volume, frequency, and duration of Lake Powell deficits after drought operations have been implemented. When a deficit occurs at Lake Powell, after accounting for drought operations, the model assumes that an amount of water sufficient to bring Powell back above elevation 3525 is "injected" into the reservoir. This model construct allows the simulation to continue with an assumed amount of demand management water without having to make assumptions about which water users would be subject to reduced consumption (voluntary or otherwise).

B. Lower Basin DCP

The Lower Basin (LB) has proposed an aggressive DCP in which the states are subject to escalating reductions in allocations totaling 1.1 million acre-feet (This included obligations under the 2007 Interim Guidelines; the total is 1.325 maf when combined with Reclamation and Mexico participation; Figure 2). The LB DCP proposal includes a recovery provision whereby the states may recover a portion of the DCP water under certain conditions. Both of these components of the LB DCP are included in the Risk Study model. Other minor provisions of the proposed LB DCP including criteria for recovery of ICS and changes to the evaporative charges for ICS water are relatively minor components, and are not included in the model. Figure 2 below shows the escalating LB conservation targets as Mead drops, including contributions from Mexico and Reclamation.

Lake Mead Elevation	AZ Total	NV Total	CA Total	USBR	Mexico Minute 319*	Total
1,090-1,075	192,000	8,000	0	100,000	0	300,000
1,075-1,050	512,000	21,000	0	100,000	50,000	683,000
1,050-1,045	592,000	25,000	0	100,000	70,000	787,000
1,045-1,040	640,000	27,000	200,000	100,000	70,000	1,037,000
1,040-1,035	640,000	27,000	250,000	100,000	70,000	1,087,000
1,035-1,030	640,000	27,000	300,000	100,000	70,000	1,137,000
1,030-1,025	640,000	27,000	350,000	100,000	70,000	1,187,000
<1,025	720,000	30,000	350,000	100,000	125,000	1,325,000

Figure 2. Proposed Reductions under the Lower Basin Drought Contingency Plan.

C. Demands

Lower Basin demands and Mexico deliveries are as previously modeled for the DCP process. For the Upper Basin, we began Phase I modeling using Scenario A (Current Trends) from the Colorado River Basin Study dataset. Feedback from participants (specifically Kerry Sundeen representing the Front Range Water Council and Robert Wigington of The Nature Conservancy) led us to re-evaluate the demand schedule for the upper basin. Modeled depletions under Scenario A were both higher than recent historical data suggested (Reclamation's Consumptive Use and Loss reports) and had forecasted growth in consumptive uses higher than the recent historical rate (which has been essentially zero for the last 10 years). Given that one of our objectives is to accurately portray the current risk to the Upper Basin, we modified the demand schedule to better reflect current conditions. The D1 schedule from the Basin Study, with a 10% reduction in depletion requests across

all upper basin water users, was determined to provide a reasonable reflection of both current consumptive uses and a lower rate of growth than the Scenario A schedule. This new demand schedule was used for the remainder of the study, and is referred to herein as the "90%D1" demand schedule. Figure 3 below compares modeled depletions in Colorado using the 90%D1 schedule to the actual depletions for Colorado as reported in Reclamation's Consumptive Uses and Losses Reports. While the year-to-year variability between the two datasets is obvious, the long-term averages as shown in the inset box are very close.

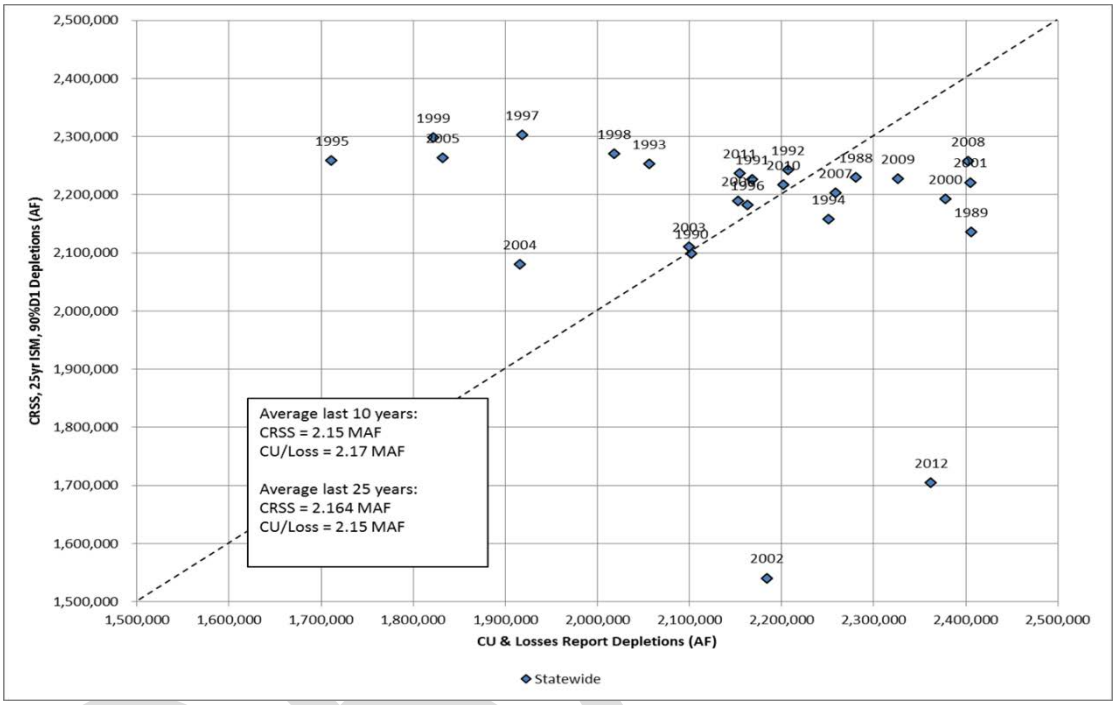

Figure 3. Modeled (CRSS) vs reported consumptive uses in the Upper Basin, 1988-2012, using the updated demand schedule 90%D1. (Reported values from Reclamation's Consumptive Use and Loss Reports)

D. Hydrology and Simulation Period

Three different hydrologic data sets were used in the study:

1. Historical period 1988-2012 (the "Stress Test" period, used in the DCP process)
2. Historical period 1950-2012 (corresponding approximately to the original CRWAS study period)
3. CMIP-3 Climate Change Hydrology (as used in the Basin Study)

Results were presented for all three hydrologic traces during the webinar series, but the focus of most analyses were on the Stress Test period.

E. Operational Scenarios

Several different operational assumptions were simulated in Phase I. These included combinations of Upper Basin and Lower Basin DCP, with and without assumed demand management actions in the UB. Additionally, some of the simulations presented in the second webinar included different minimum pool assumptions for Flaming Gorge. Given the original objective of the study – to quantify potential amounts of storage deficit at Lake Powell required via demand management – and the key operating assumption that both DCPs will be enacted with their current conditions largely intact, the majority of the results shown reflect those operations. Specific scenario assumptions as presented during the webinar series are described in Appendices A-C.

F. Initial Conditions and Compact Accounting

The 24-Month Study (24MS) forecasts for January 1 2016 storage conditions were used as initial conditions for all reservoirs. Initial conditions were updated based on the most current forecasts available.

The current-year compact accounting balances were input in the model (through 2015). To track the 10-year Lee Ferry flows, the previous 9 years of data were used with the first simulation year to track 10-year flows throughout the simulation period. There is no compact flow requirement within the model. Unlike the version of CRSS used for the Basin study, which provided for a minimum 10-year volume of 8.23 maf by creating an artificial augmentation flow at Lee Ferry, the version used herein makes no assumptions about compact flow requirements when setting reservoir operations.

G. Coordinated Operation and Forecasting

For Interim Guidelines operations of Lakes Powell and Mead, the operations tiers are determined using the August 24-month study projections of January 1 Powell and Mead pool elevations. Predictions for Lake Powell's storage and elevation are based on inflow forecasts from the National Weather Service's Colorado Basin River Forecast Center. Adjustments can be made on April 1 using the runoff forecast for April through September, or on a more frequent basis if operations are governed by an equalization or balancing tier.

For planning studies in CRSS, the tier is normally assigned in January based on December 31 Powell storage. Because extended operations is triggered on either April 1 or August 1, a forecasting method was needed within CRSS that would mimic the forecasting that occurs in reality. A regression equation was developed that relates predicted and actual inflows to Powell, using data from past 24-month studies. This inflow estimation includes an error term that varies in magnitude based on the predicted mean value, and provides both 90% exceedance (minimum inflow), and most probable (50% exceedance) inflow estimates.

In April and August, the model forecasts the following April's Powell storage and pool elevation. If the forecast elevation falls below the trigger elevation, then a forecast deficit is computed as the

difference between the two. For example, if the forecast predicts an elevation of 3510 on April 1, and 3525 is the trigger elevation, then the deficit is the amount of water required to bring the elevation from 3510' to 3525' (about 880 kaf). A deficit determination will then trigger extended operations rules at all of the upper CRSP reservoirs simultaneously. Most of the model results shown here utilize the forecast trigger, but do not limit extended operations to the specific deficit volume predicted.

IV. Summary Results and Discussion

Phase I of this study served to validate previous work on the Drought Contingency Plans for both Upper and Lower Basins, and to lay the foundation for future phases of this study. It also served as a valuable review of the CRSS modeling platform, allowing stakeholders an opportunity to understand the model strengths and weaknesses, and afforded an opportunity to refine the model demand schedule to more accurately reflect recent reported consumptive use data. Appendices A-D consist of slides from the three webinar series plus the final BRT presentation, and provide a summary the results of the modeling done thus far. This section summarizes those results.

The stated purpose of this work was to answer the following questions:

1. What are magnitude and duration of Powell shortages below elevation 3525'?
2. How much of the above shortages can be met by contributions from Drought Operations of CRSP reservoirs?
3. How much consumptive use reduction ("demand management") would be needed by Upper Basin states - AFTER use of stored CRSP water - in order to maintain Powell pool elevations?

CRSS modeling indicates that shortages at Lake Powell (defined here as pool elevation less than 3525') and Lake Mead (<1020) are likely to occur in the future, absent the implementation of drought contingency plans. With DCPs in place for both basins, the likelihood of these critical events is significantly reduced, but not eliminated. The Upper Basin's first line of defense, releasing water from upstream CRSP reservoirs, can contribute up to approximately 2.0 maf. That volume is not always required in full to offset the modeled shortage, but conversely it is also insufficient in the worst events to fully offset the shortage. Although the likelihood of extreme shortages occurring is small, the implications to the upper basin are significant, as are the volumes that would be required to fully offset those shortages (Figure 4). The figure shows that using current demands (90%D1) a repeat of the droughts seen in the Stress Test period hydrology could require as much as 2 million acre-feet of water to fully eliminate all risk to Lake Powell. Approximately 2/3 of those events could be prevented with 1.0 MAF or less. The results also shows the sensitivity of risk to increasing demands. If the upper basin consumptive uses were increased by approximately 10% (shown as Demand Schedule A below), the frequency and magnitude of the modeled shortages increases significantly.

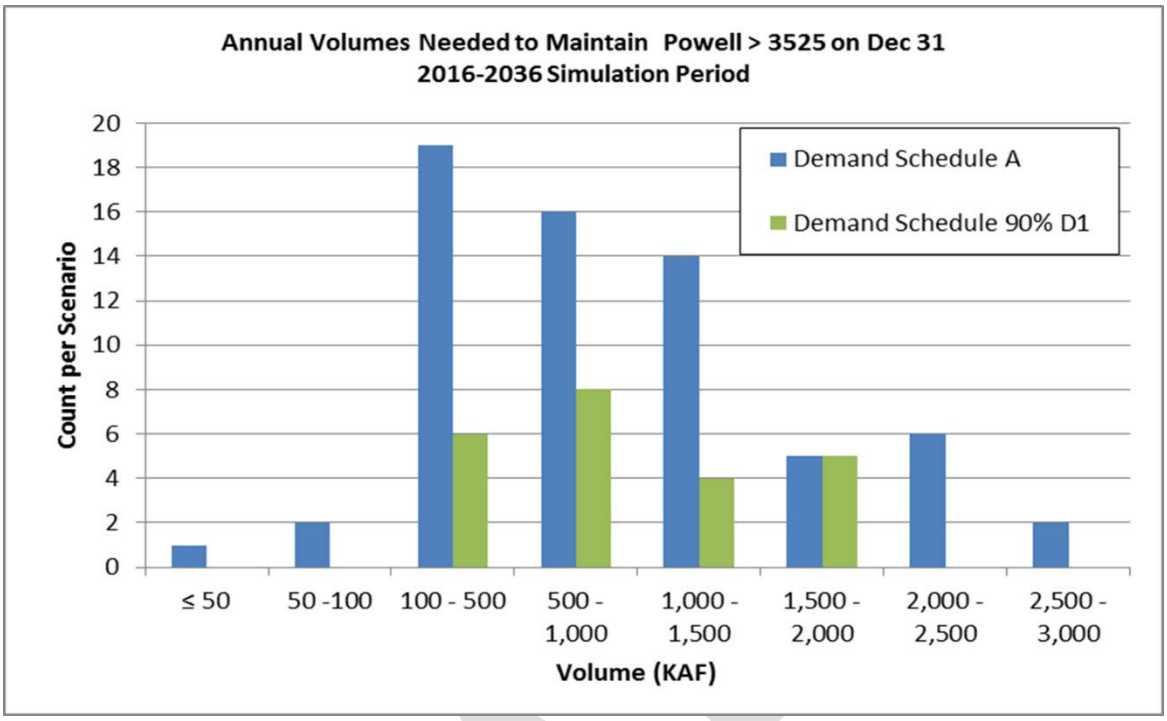

Figure 4. Volumes required AFTER CRSP drought operations to maintain Powell at 3525'.

The analysis from Phase I indicates that the risks to Lake Powell in the face of ongoing drought are real, and need to be addressed. Drought Contingency Plans that are currently proposed for both the Upper and Lower Basins provide a significant reduction in that risk. Unfortunately, the models are only as good as the information we provide them. We cannot accurately predict future hydrologic conditions in the basin, which are the single largest driver of risk. Modeled demands are also a significant driver of risk, and the limitations of CRSS are apparent when looking at modeled depletions during extreme drought events. Perhaps the most significant limitation in the model with respect to Colorado's water use is the current inability of the model to accurately reflect storage by non-CRSP projects and variability in water demands for trans-basin diversions. While the model does a good job of capturing the long-term depletion averages, its lack of representation of these features makes its individual year depletions differ from reported values. StateMod may offer some help in better simulating the significant non-CRSP storage in the upper Colorado, but even it does not do a good job of reflecting east-slope demand variability and its impact on west slope diversions, storage, and delivery.

V. Recommendations and Next Steps

Moving forward to Phase II, the BRTs and other stakeholders are providing feedback on the modeling thus far, and have been encouraged to propose additional scenarios for analysis. Preliminary scoping for Phase II is focusing on two areas: refined simulations using CRSS, to examine concepts such as water banking and sensitivity of risk profiles to model inputs; and examination and

preliminary analysis of StateMod simulations to look more closely at impacts of compact curtailment and trans-basin storage and diversions. A preliminary Scope of Work has been prepared for submission to the CWCB, and is included in the appendices.

VI. Appendices (Attached Separately)

A. Webinar 1
B. Webinar 2
C. Webinar 3
D. Basin Roundtable Presentation
E. Proposal for Phase II
F. Kuhn memo to Boards
G. Hydros UCRC Contingency Plan Report