Colorado River District
Protecting Western Colorado Water Since 1937

MEMORANDUM
SEPTEMBER 13, 2016

TO: BOARD OF DIRECTORS, CRWCD

FROM: ERIC KUHN

SUBJECT: ***JOINT WEST SLOPE ROUNDTABLES RISK STUDY RESULTS SUMMARY AND THOUGHTS ON THE NEXT STEPS***

KEY FINDINGS

- Droughts similar to those in the recent past could cause Lake Powell to, within a few years, drop to levels that jeopardize Glen Canyon Dam's ability to generate electricity, and create a risk that the Upper Colorado River Basin would be unable to meet its delivery obligations under the 2007 Interim Guidelines and potentially the Colorado River Compact.
- The higher the consumptive use in the Upper Basin going forward, the greater the risk to all water users.
- Water supply augmentation and "drought operations" – moving water from large upstream reservoirs to prop up the levels in Lake Powell – reduce risk.
- "Demand management" – the voluntary reduction of consumptive use in the Upper Basin – can further reduce risk.
- In the most extreme drought scenarios, even after drought operations and additional demand management in the Lower Basin, the shortfall may be too large to meet with demand management programs, suggesting the need for discussions now about the necessary tradeoffs and alternative strategies to meet worst case scenarios.

SUMMARY

The Joint West Slope Roundtable Risk Study (first phase) is nearing completion. The study results confirm much of what we already knew about the need for and operation of the Upper Basin contingency plan, and the results provide valuable new information concerning the impacts of different demand levels and the size and frequency of the amount of water that Colorado might have to provide under the demand management component of the plan.

The study results suggest that at today's level of development in the Upper Colorado River Basin and assuming hydrologic conditions similar to what we've experienced since 1950, without a contingency plan in place, storage in Lake Powell could fall below the minimum power elevation of 3,490' (4 million acre feet (MAF) above the dead pool). If Lake Powell levels are allowed to drop below 3,490' hydroelectric power generation is lost resulting in a significant loss of power revenues to the Department of the Interior. These revenues fund project operations, repay the federal treasury for project investments and fund vital environmental programs. Further, if Lake

Powell storage is allowed to fall below minimum power, releases from Glen Canyon Dam are restricted to the outlet works and, under low head conditions, releases are restricted to the point where they are insufficient to meet the 2007 Interim Guidelines requirements potentially putting Colorado and the other Upper Division states into a compact deficit situation.

The study also shows that if contingency plan measures are in place to maintain storage in Lake Powell above a target elevation of 3,525' (6 MAF above dead pool and 2 MAF above minimum power), the risk of Lake Powell falling below minimum power is very small and the risk of a compact deficit is even smaller.

The proposed Upper Basin contingency plan has three elements: (a) augmentation (primarily in the form of cloud-seeding), (b) CRSP drought operations (i.e., moving available water from the upstream Flaming Gorge, Aspinall, and Navajo units of the Colorado River Storage Project downstream to increase levels in Lake Powell), and (c) demand management (reducing upstream consumptive uses). When additional water is needed to maintain the 3,525' target elevation (referred to as "shortages"), the shortage often can be offset by CRSP drought operations. However, in some situations, both CRSP drought operations and demand management will be required to address the shortage. For those shortages that require demand management, a portion can be addressed with theoretically "manageable" cutbacks (less than about 300,000 acre-feet for the Upper Basin as a whole), but for those rare deep droughts similar to those experienced in 1953-1956 or 2001-2005, the total shortages that would have to be addressed through demand management are very large, over 500,000 acre-feet and possibly as high as 2,000,000 acre-feet. For a shortage this large, it's inconceivable that this amount of water could be obtained through demand management cutbacks in one, or even two years. For these severe drought periods, we will have to look at strategies that bank a feasible amount of demand management water in a large reservoir over an extended period of time. Or, the Upper Division states could find that given how rare these severe droughts are and the high cost of providing demand management water, the risk is acceptable. Remember by picking a target elevation in Lake Powell of 3,525', we already have a cushion over the 3,490' minimum power elevation, but we should also understand that while 3,490' is the design minimum power to protect the turbines, the Bureau of Reclamation will have to shut them down above 3490'.

Finally, the study confirms that demand levels and hydrologic assumptions matter. For the study purposes, we initially used a demand schedule prepared for the Colorado River Basin Study (USBR and seven states-2012) referred to as "current trends" or schedule A. This schedule results in modeled depletions that, on average, are about 400,000 acre-feet per year higher than recent actual depletions. Thus, we also used a slow growth schedule from the Basin Study, referred to as D1 and further adjusted it down by 10%. This schedule, referred to as 90% D1, more accurately represents actual Upper Basin depletions from the Consumptive Uses and Losses reports for the last several decades. The difference in risk between the two is quite stark. Under the higher demand level of schedule A, there are almost three times as many shortages and those shortages are larger and occur in multiple years. While the 90% D1 schedule more accurately represents current water use reality, the schedule A model results are a reminder that significantly increased water use in the Upper Basin significantly increases the risk of shortfalls at Lake Powell.

The differences in shortages based on the hydrologic assumptions, reflecting the model's supply side, are more subtle than stark. We considered three different hydrologic periods: 1988-2012, referred to as the "stress test" period, 1950-2012 the long-term record (picked to coincide with the period of record used in the Colorado Water Conservation's Board's (CWCB) Colorado River Water Availability Study), and climate change hydrology from the Basin Study. The major difference between the 1988-2012 and 1950-2012 periods is that under the longer term record the frequency (or risk) that demand management will be needed is slightly reduced because from the mid-1960s through the mid-1980s, there was only one relatively mild multi-year drought (1974-1977). However, from a policy perspective, the results are very similar, the 1950–2012 hydrology has the same droughts as the 1988-2012 period PLUS the very severe 1950s drought. Under the climate change hydrology, the frequency that demand management is needed is about the same as or less than the stress test period, but when droughts do occur, they're more severe and the shortages are greater.

STUDY DETAILS

Assumptions

1. The 2007 Interim Guidelines were assumed to be in place throughout the full 2040 study time period. Technically the Interim Guidelines expire on December 31, 2025, but cover water year 2026. I consider this a fairly safe assumption. Negotiations to renew the Interim Guidelines will begin within a few years. It's possible that all seven states and the Department of the Interior might agree on a few tweaks to the existing guidelines, but I consider it very unlikely that the 2007 Interim Guidelines will undergo significant revision. It's important to remember that the 2007 Interim Guidelines preserved the 8.23 MAF per year (on average) release from Lake Powell, plus the concept of equalization of water levels between Lake Powell and Lake Mead. The guidelines provide additional flexibility, allowing releases to drop as low as 7.48 MAF/year -2014 and as high as 9.0 MAF (2015, 2016 and 2017), but IN THEORY, the years of 7.48 balance out the 9.0s.

2. A second major assumption is that the three Lower Division states will successfully implement their proposed "voluntary" reduction plan as the primary component of their contingency plan. This plan would put in place 600,000 acre-feet of additional Lower Basin demand management as Lake Mead approaches 1,025'. This 600,000 acre-feet of demand management together with the 500,000 acre-feet of shortages required by a tier III shortage under the 2007 Interim Guidelines plus additional savings by Mexico and the Bureau of Reclamation provide a total reduction in demand that exceeds 1.2 MAF. The modeling suggests that this would be sufficient to stabilize storage levels in Lake Mead above the critical elevation of 1,010'.

Because Lake Powell and Lake Mead are linked through the Interim Guidelines, implementation of the Lower Basin demand management plan significantly benefits storage levels in Lake Powell and reduces the risk of Lake Powell dropping below elevation 3,525'.

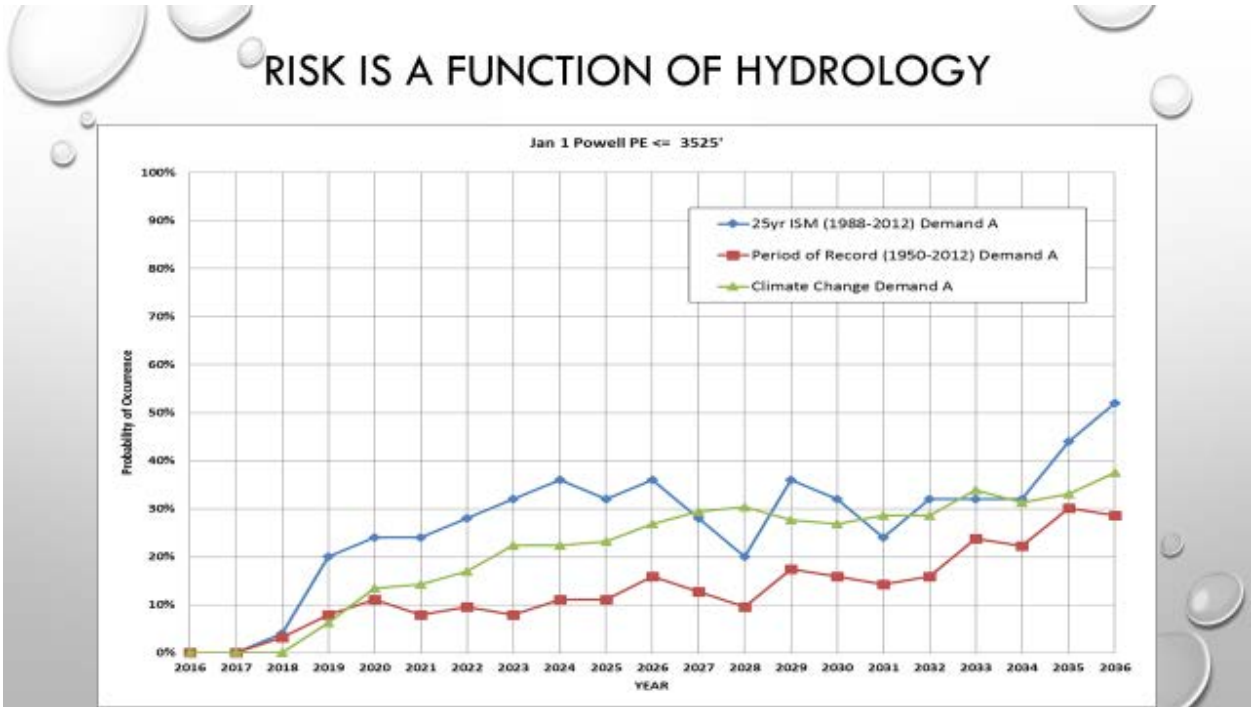
How safe is the assumption that the Lower Basin will successfully implement its plan? It's probably a good assumption. The plan details may be tweaked, but the goal of conserving an additional 600,000 acre-feet is unlikely to change. They've already made significant progress for 2016, consumptive use from the lower mainstem has dropped from 7.5 MAF to about 7.2 MAF (the initial estimates were for a 500,000 acre-feet reduction, but this turned out too good to be true).

3. The third major assumption is that the Bureau of Reclamation and the Upper Division states will successfully implement drought operations of the upstream CRSP storage units (Navajo, Flaming Gorge and Aspinall), using releases from the big upstream reservoirs to protect levels in Lake Powell. This is a very safe assumption. The states and Reclamation are close to reaching an agreement to implement the plan.

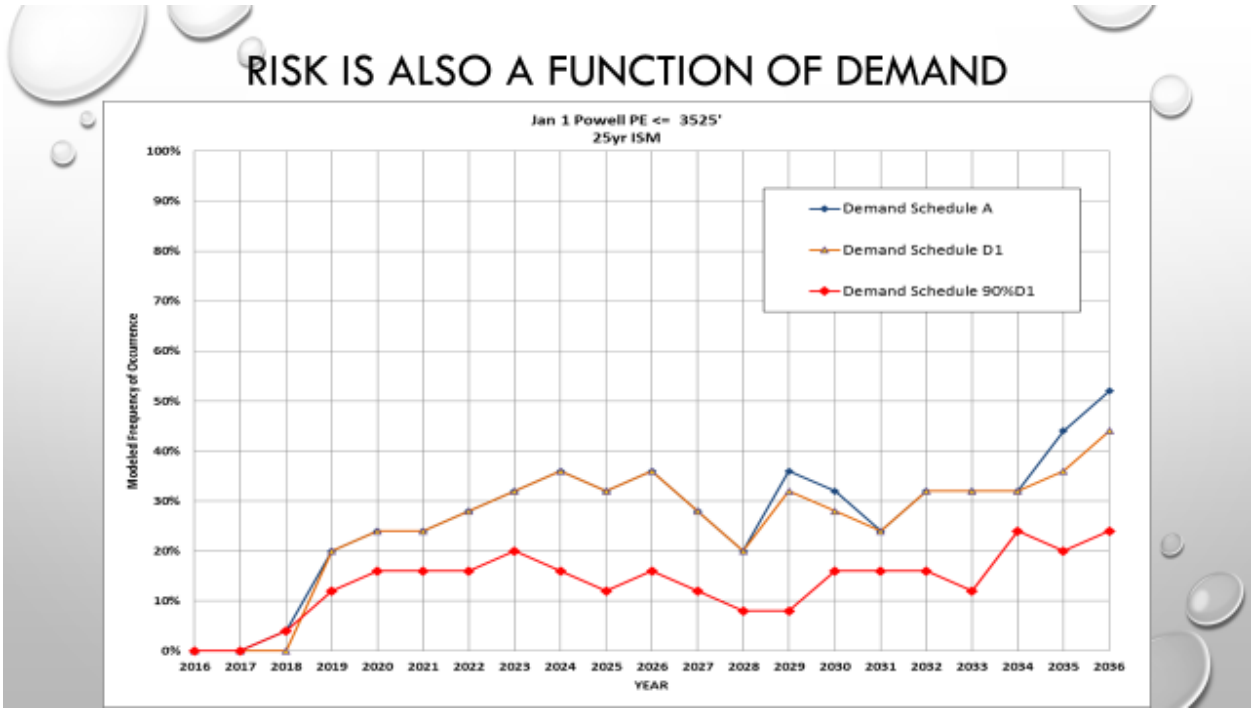
4. The study determined the amounts of demand management of the four Upper Division states as a whole, it did not determine the specific amount that would be allocated to Colorado, or any sub-basin within Colorado. The Upper Division States have made no decision on how to allocate demand management among themselves. However, under the 1948 Upper Colorado River Basin Compact, Colorado's apportionment is 51.75% and based on recent data, Colorado's share of the total consumptive use in the four states ranges between 55–58%. It would be reasonable to assume Colorado's share of demand management would be in this range.

EXAMPLES OF DETAILED RESULTS

The best example to show the results of the study are the following three graphs. The first graph shows the difference in risk with three different hydrologic assumptions, 1988-2012, 1950-2012 and climate change. This graph shows the risk of Lake Powell dropping below 3,525' over time without any action. As you can see, the longer term hydrology shows the lowest overall risk, but there is significant risk for all three different hydrologic assumptions.



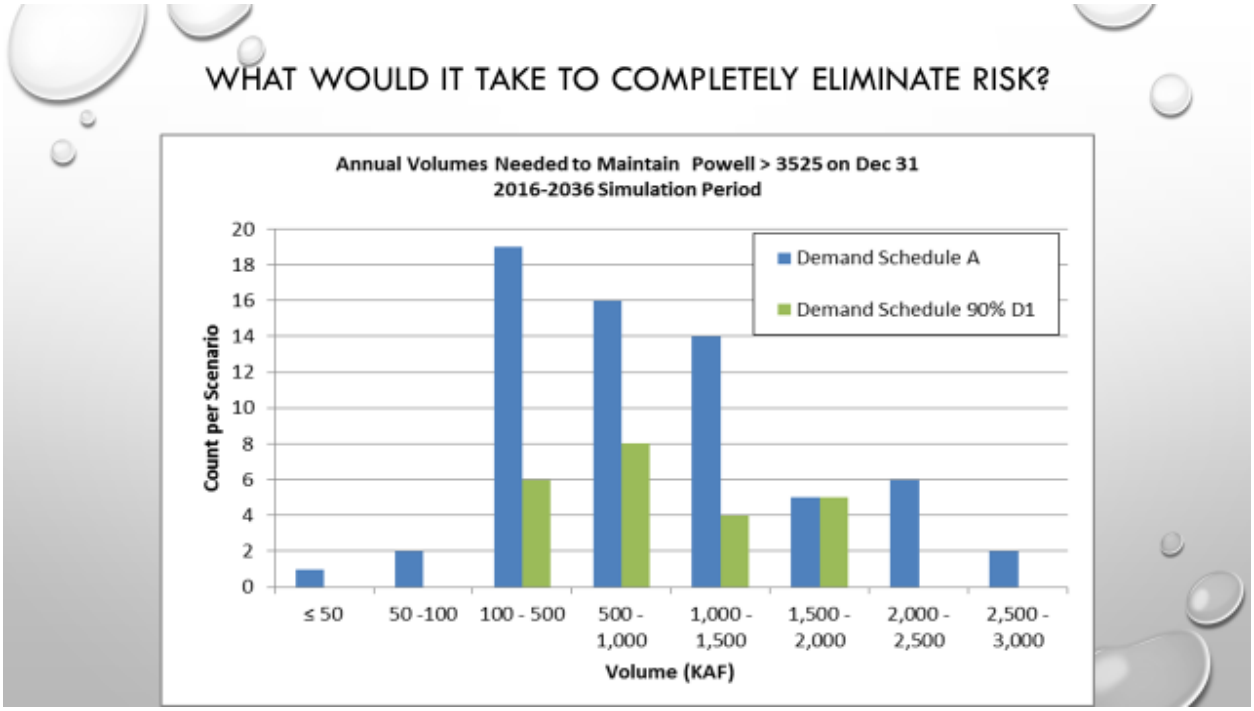
The second graph shows the risk of shortages (without action) under three different demand/consumptive use assumptions. Under demand schedule A, consumptive uses are about 10% higher than demand schedule 90% D1. This shows that an increase in Upper Basin demand above current levels substantially increases risk.



The third graph shows a distribution of the number and size of shortages under two different demand/consumptive use assumptions. Unlike the first two graphs, this graph assumes both successful implementation of successful CRSP drought operation in the Upper Basin and demand management in the Lower Basin. Based on the Consumptive Uses and Losses report, prepared by the Bureau of Reclamation with data from the states, the Upper Basin is currently consuming about 4 MAF per year (not counting CRSP reservoir evaporation which is apportioned to the states under the 1948 Compact, but calculated separately by the basin model used for the study.) The model used for this study is referred to as the Colorado River Simulation System (CRSS). All of the demand schedules from the Colorado River Basin Study show Upper Basin consumptive uses higher than four MAF per year as of 2015 so we adjusted schedule D1 10% downward to more accurately reflect current patterns of use – thus a 90% D1 run. Using this demand schedule, CRSS replicates existing consumptive uses within Colorado and the Upper Basin within a few percentage points.

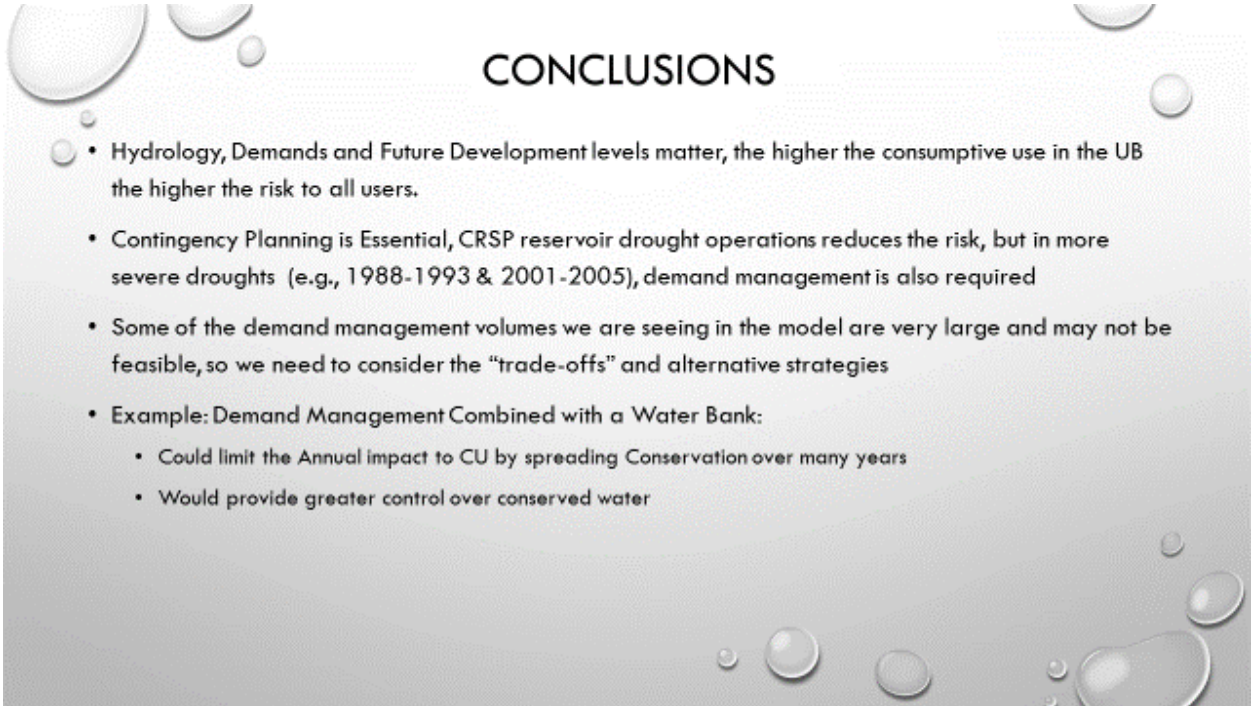
The green bars show the distribution of shortages under this 90% D1 run. As you can see, even with the assumption that the Lower Basin has reduced its use by up to 1.2 MAF per year and the CRSP drought operations have been implemented, there are a few large shortages.

The blue bars show the distribution under a larger demand schedule. Under this demand schedule, Upper Basin consumptive use is about 10% higher than the 90% D1 run. An increase of 10% in Upper Basin use more than doubles the frequency of shortages that might have to be met through demand management. It also increases the number of very large shortages that are likely beyond our ability to meet by demand management.



STUDY CONCLUSIONS AND POLICY ISSUES

Shown below are the study's conclusions we presented to each of the roundtables. We tried to keep the message simple and straightforward.



There are a number of significant policy issues raised by the study results. Recall that the Colorado Water Plan includes a seven principle "framework." The study is most relevant to principle #4 "a collaborative program that protects against involuntary curtailment is needed for existing uses and some reasonable increment of future development in the Colorado River System, but it will not cover a new transmountain diversion." Our assumption has always been that the collaborative program would be very similar to the contingency plan currently under development. There would be three basic elements: augmentation, drought year operation of the upstream CRSP storage units and demand management.

The study suggests that we need to begin to have a more serious and focused discussion within Colorado and the other Upper Division states on demand management. How would demand management be implemented and administered? How would the costs of demand management be covered? How is demand management water going to be delivered past other users from the source of conservation to Lake Powell? At what point do the costs of demand management exceed the benefit? In other words, at what point is the risk of Lake Powell dropping below minimum power so low and the costs of avoiding that risk so high that we choose as a policy matter to accept the risk?

We've always assumed that a water bank would be one tool for implementation of management of risk. What are the other options? How can the burden of demand management be shared between

East Slope/West Slope and municipal/agriculture such that a demand management program will not have a detrimental impact on West Slope agriculture and locally-impacted communities?

Within Colorado, in developing and implementing a demand management program, what are the roles of the CWCB, the Colorado River District and the Southwestern District? What are the roles of the basin roundtables and Inter-Basin Compact Commission (IBCC)?

Principle #1 from the Water Plan's "Framework" also is quite relevant: "east slope water providers are not looking for firm yield from a new transmountain diversion and the project proponent would accept hydrologic risk for that project." The explanation provides more detail–"a new transmountain diversion would avoid increasing either the risk of a Compact deficit or the burden on existing uses in a demand management program." The risk study didn't directly address this question. However, it is very clear from the results that not increasing the burden on existing uses in a demand management program is a very high bar. As a practical matter, about the only way to do this is to allow a new transmountain diversion to divert only when Lake Powell is delivering surplus water to the Lower Basin. This is referred to as "equalization" and is discussed in more detail below. During wet periods like the early 1980s or late 1990s, there might be plenty of water, however since 2000, Powell has only equalized twice.

NEXT STEPS AND FOLLOW UP STUDIES

There is agreement among the West Slope roundtables that we need to continue the study process into the next phase(s). As we expected, the risk study has raised a number of additional questions. I believe that the next phases of the study should focus on four basic areas:

1. Additional hydrologic analysis using CRSS. There are suggestions that we conduct additional modeling using flows from the paleo-hydrologic record and there are questions concerning the 3,525' management trigger – why not 3,510' for example.

2. The study results suggest some rare, but very large shortages that might have to be made up through demand management. We need to model alternative approaches where we bank a smaller amount of water in a reservoir in more years and hold that water for delivery in the large demand management years.

3. Using both CRSS and CDSS (state mod) explore how different management options impact water uses, reservoir storage, and the major sub-basins. We would look at a variety of options, many (or most) of which someone will object to. The objective is to look at where the water for demand management might be found:

a) A reduction of water uses based on priority.

b) A pro-rata reduction of all major post-compact rights.

c) A pro-rata reduction of consumptive use within each basin based on either the consumptive use within each basin or that basin's average contribution to the Colorado River System's natural (undepleted) flow.

d) A combination of a, b and c with a pre-compact water bank.

e) Other options suggested by stakeholders.

4. Conduct additional modeling based on the updated climate model results if the data needed to conduct such modeling becomes available.

Because of uncertainties with Colorado's CDSS model (state-mod), we're considering splitting the next phase into two phases. The first phase (2a) would cover questions 1 and 2 and we would conduct some test runs with state-mod to evaluate the use of the model (see the attached email from John Carron describing his meeting with the East Slope technical group.)

Under phase 2b, we would make a detailed study of the options under question #3, but might require some improvements or modifications to state-mod. Splitting the next phase in two also makes sense from management, budget, and roundtable buy-in perspectives.

FREQUENTLY ASKED QUESTIONS

During the presentations to the roundtables and IBCC there were a number of commonly or frequently asked questions.

1. What is the current status of the Upper Basin's compact obligations at Lee Ferry? The answer is that the Upper Basin has always delivered more than its obligation at Lee Ferry. The current 10 year gage flow at Lee Ferry is over 90 MAF. The problem is that there is no real agreement on the actual minimum obligation. It could be as low as 75 MAF or as high as 83 or 84 MAF every 10 years. Article III (d) of the 1922 Colorado River Compact is quite clear. It requires the States of the Upper Division to not deplete the 10 year flow at Lee Ferry below 75 MAF. HOWEVER, in addition to Article III (d), Article III (c) requires the Upper Basin to provide one-half the deficiency in the obligation to Mexico when it can't be met through a surplus. The treaty obligation to Mexico is 1.5 MAF. Thus, in theory, if there is no surplus, the Upper Division states would have to provide another 750,000 acre-feet per year, or 7.5 MAF over ten years, for a total of 82.5 MAF over every 10 year period.

The Upper Division states have always taken the position that the 1922 Compact parties have never agreed on when a deficiency exists and how to quantify such a deficiency, therefore III (c) is an unquantified obligation. The Lower Division states take the position that, at least since 1998, there is no surplus (every drop of the river is used) and further, the Upper Division states must cover transit losses from Lee Ferry to Mexico, about 100,000 acre-feet per year. The bottom line is that the Upper Division's obligation could be anywhere from a minimum of 75 MAF every ten years to 83.5 MAF every consecutive ten

years (the 83.5 includes transit losses to Mexico). Since the filling of Lake Powell, the lowest 10 year flow at Lee Ferry was 84.77 MAF from 2001 - 2010.

2. If the Upper Division states' obligation at Lee Ferry is 75 MAF every ten years (an average of 7.5 MAF per year) plus an unquantified (and disputed) obligation to Mexico, why were releases from Lake Powell in water years 2015 and 2016 approximately 9.0 MAF? The answer is Glen Canyon Dam releases are set by the 2007 Interim Guidelines. Under these guidelines, Glen Canyon Dam (Lake Powell) and Hoover Dam (Lake Mead) are operated in a coordinated manner. Prior to the adoption of the 2007 Interim Guidelines, Glen Canyon Dam was operated in one of three modes: a minimum objective release of 8.23 MAF per year, when storage is less than equalization level, equalization with Lake Mead when storage in Powell is above the equalization level, AND active storage in Lake Mead was less than Lake Powell, and finally during very wet periods, Lake Powell was operated to fill without spilling.

The states informally "agreed" to the minimum objective release level of 8.23 MAF in the late 1960s/early 1970s in a process that was referred to as the "the committee on probabilities and test studies." In theory, 8.23 maf was not an interpretation of the compact, but a minimum release amount that all of the states could live with. In practice it was more of a "shotgun marriage." It was about the only alternative that would not result in litigation.

The states went into the negotiations of the 2007 Interim Guidelines with the 8.23 maf as a "baseline" condition. In theory, the guidelines preserved the 8.23 maf release on average, but provided additional flexibility so that when storage conditions are a little better in Lake Powell than Lake Mead, releases can be bumped up from 8.23 to 9.0 MAF per year. Alternately, when storage conditions in Lake Mead are better than Lake Powell, then releases can drop to 7.48 MAF per year. Actual releases are controlled by the four tiers set forth in the guidelines. This flexibility was intended to allow Mead and Powell to more closely follow each other during droughts and recoveries.

Thus, in water year 2014, which followed the 2012 and 2013 dry years, the Glen Canyon release was 7.48 MAF. However since 2014 the runoff into Lake Powell has been in the 90-100% range, so Powell storage has recovered to the point where releases for water year 2015, 2016 and very likely 2017 will be 9.0 MAF per year. Current storage in Lake Powell is 13 million acre feet, while Lake Mead is at 9.6 million acre feet.

3. What is equalization and why is it important to the Upper Basin? Answer: Section 602(a) of the 1968 Colorado River Basin Project Act requires the Secretary of the Interior to propose coordinated long-range operating criteria and sets the priorities for releases of water from Glen Canyon Dam (Lake Powell). The first priority is for delivery of the Upper Basin obligation to Mexico, if any. The second priority is delivery of the 75 MAF over 10 years under Article III (d) of the 1922 Compact. The third priority is equalization. Article III (e) of the 1922 Compact prohibits the Upper Basin from withholding and the Lower Basin from requesting water that can't be reasonably applied to domestic or irrigation purposes. The policy question facing the basin in 1968 was when is storage in the Upper

Basin in violation with Article III (e)? The concept of equalization was intended to answer this question.

After releases are made for the first two priorities, additional equalization releases are to be made IF 1) the active storage in Make Mead is less than the active storage in Lake Powell, AND 2) storage exceeds an amount determined by the Secretary of the Interior needed to "assure deliveries under clauses (priorities) (1) and (2) without impairment of annual consumptive uses in the upper basin pursuant to the Colorado River Compact." The act requires the Secretary to consider all relevant factors including "the most critical period of record." This is commonly referred to as the 602(a) level or 602(a) elevation. As a practical matter, consider it the amount of water that needs to be in storage in the Upper Basin so that the states of the Upper Division can meet both their internal Colorado River needs and their obligations under Articles III (c) and (d) of the 1922 Compact.

For example, assume the equalization level is 16 MAF and that projections show that with a normal release of 8.23 MAF at the end of the water year the active storage in Powell would be 19 MAF and in Mead would be 17 MAF. Thus, storage in Powell is above the equalization level and it has more storage than Mead triggering an additional equalization release. In this case if Powell releases were increased by an additional MAF for a total of 9.23 MAF, then at the end of the water year each reservoir would have an active storage capacity of 18 MAF and their storage would be equalized.

In the late 1970s, the Bureau of Reclamation developed an algorithm (formula) to determine the 602(a) level. Like the 8.23 MAF minimum objective releases, the states accepted but never legally or formally agreed to it. The key variables are the level of upstream development, the assumed drought of record, and the downstream minimum release. The 2007 Interim Guidelines includes an equalization table. The table shows that the equalization level in Powell increases 3' every two years. For water year 2017 the equalization level is 3,652 or 17.5 MAF (as of September 6, 2016 the storage in Lake Powell is at 3,613' or 13 MAF).

Since the early 2000s, Lake Powell has only made equalization releases twice. A small release was made in 2008 (750K) and a larger 4 million-acre foot + release after the large 2011 runoff year. An example of the importance of equalization is 2011. Had the equalization level in Lake Powell been 2 MAF higher than it was, today Lake Powell would have 2 MAF more storage (15 million versus 13 million) and Lake Mead would be 2 MAF lower and approaching a Tier II shortage!

I expect that equalization will be one of the more difficult and contentious issues facing the states and Interior for the renegotiations of the Interim Guidelines.

4. Is the threat of draining Lake Powell real or is it just a paper threat? Answer: This is a difficult question, but I believe the best answer is the threat is very real. HOWEVER, the risk is relatively low. The study shows that at today's development levels two conditions would have to occur before there is a real threat that we would drain Lake Powell

and trigger the need for a significant amount of demand management. First, we need a drought the magnitude of 2000-2005 or 1952-1956. AND second, the initial storage levels in Lake Powell need to be at or below 13-14 MAF. Based on historical hydrology, the risk of both of these occurring is relatively low. However, I need to point out that because Lake Powell storage is currently only 13 MAF, today we are clearly at an elevated risk. Further, some hydrologists have pointed out that based on what has actually happened since 2000, even the 1988-2012 "stress test" hydrology may be too optimistic. The 1988-2012 period had a mean natural flow at Lee Ferry of 13.3 million-acre feet per year. The estimated mean natural flow at Lee Ferry for 2000-2016 is only 12.5 MAF per year. NOTE, the annual natural flows for 2014-2016 are still preliminary estimates. If the hydrologic conditions we've experienced in the Colorado River Basin since 2000 continue on into the future, the risk of draining Lake Powell is substantial.

REK/ldp
Attachment