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# Comments on the Colorado River Water Availability Study Phase 1 Report

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## Summary

The Colorado River Water Availability Study investigates the impacts of climate variability and change on the availability of water in the state. This is the first study to investigate the impacts of anthropogenic climate change on the Colorado River in our state that includes detailed modeling of water rights. It builds on and integrates with decision support tools including StateMOD and StateCU that were developed previously. This study represents an important step forward in supporting the development of climate change adaptation strategies in Colorado, and we compliment the CWCB and the consultants on their work.

In addition, this work helps develop the modeling framework and tools to enable the State of Colorado to make continuing assessments of impacts on the State's water resources as new scientific information about climate change becomes available. This ability will be particularly relevant as the results from the next internationally coordinated climate modeling program, CMIP5, become available starting in 2011.

These results need to be considered in the context of other studies on the future of the Colorado River. Many of these are summarized in the CWCB "Climate Change in Colorado" Report and references therein. When the average over many models is looked at, the same picture appears – a likely decline in the flow of the Colorado River at Lees Ferry, driven largely by increased temperatures. In this study and in the larger literature, individual model traces ("scenarios") can show increased streamflow, however, reflecting uncertainty in future precipitation trends. One of the more striking results of the study is that the southern parts of the basin show larger impacts than the northern part. It should be noted that this is broadly consistent with the continental-scale picture of climate change – wetter conditions are projected to the north of Colorado and drier to the south.

Finally, we have some concerns about the way that the results are portrayed and have recommendations for improving the report. Our main recommendations are as follows:

- The use of terminology should be made consistent throughout the report and the main terms should be defined in the Executive Summary.

- The assumptions and methods used in the "compact considerations" part of the study be described in much more detail in the report and related to the "in state" modeling with greater clarity.
- The scenarios for 2070 should be augmented in a cost-efficient manner to make them more useful for Phase 2, and they should presented in more detail.
- The impacts of climate change on reliability should be discussed in addition to the average availability, even if only qualitatively for Phase 1.

More detailed comments are presented below.

## Presentation of assumptions and methods

Our main concern is that the results be presented in a transparent manner – so that the assumptions and limitations are communicated clearly to those may use this study.

- **The point that physical availability ("modeled streamflow") does not necessarily mean legal availability, due to both downstream in-state water rights and to potential compact considerations, should be given greater emphasis in the Executive Summary**. While this point is made in the report, it is a central message that needs clearer communication.

- **Throughout the study it is often hard to keep track of terminology**, particularly in looking at the figures. In particular, the definitions of "natural flow", "modeled streamflow" and "water available to meet future needs" (page 2-40) should be made more prominent and included in the Executive Summary.

- **The terminology is not used consistently throughout the document**. How does "Water Available to Meet Future Needs" differ from "Water Available for Future Consumptive Use"? Are "extended historical" and "paleohydrology" the same? A thorough review of the use of these terms in the figures and text is recommended.

- **The similarities and differences between the "in state" and "compact considerations" parts of the study are not clearly stated**. The commonalities and differences should be made clear in the Executive Summary. For example, the same set of climate-altered hydrologic simulations was used in both methods (with the latter covering the whole upper basin), but this is not stated in the text. On the other hand, it is not clear whether the treatment of future consumptive use by existing water rights was consistent in the two parts of the study. A table comparing the two methods is recommended.

## The "Compact Considerations" section

As noted, the study uses two different modeling frameworks – the modeling of climate change impacts within the state using stateMOD and stateCU, and the modeling of "compact considerations" using a simple mass balance model. We found it frustrating that this second part of the study, which has wide-ranging implications, was given the less attention.

- **The figure "Water Available for Future Consumptive Use by Colorado" (Figure 3-37) is confusing**, even though it will likely be the most cited graphic from this study. This figure

combines legal and climate uncertainty in a way that doesn't really give a sense of how each is contributing to the bar graph.

- **In addition, it is not stated at what level of reliability this water is projected to be "available".** It is our understanding that this graphic was developed from the average availability rather than the range over individual "re-sequenced" traces. That is, it does not include the risk from climate variability. There should at least be an acknowledgment that reliability is likely to decrease as water use approaches that which is "available".

- **The description of the method used to produce the results in this section is inadequate**. Technical memo 8-6 does describe the method in more detail, and a more complete description should be included in the report text. A description of the differences in modeling approach between the "in state" and the "compact considerations" should be included, particularly with regard to the issue of future consumptive use.

## 2070 projections

No substantive discussions of the 2070 projections are given. The CRWAS draws on recent simulations and projections by the Bureau of Reclamation using the same VIC hydrology model to portray the limited set of scenarios modeled in CRWAS in a larger context (figures 2-10 through 2-13). The report draws several conclusions from this comparison. The first is that the 2070 scenarios are not representative of the larger distribution, and the second is that the 2070 streamflow changes are similar to the 2040 changes. Based on this analysis, the report only shows results for 2040.

The first point can be remedied by performing one or two more model runs to better sample the distribution of 2070 hydrologies for use in Phase 2 of the study. We recommend that this be done as we believe the cost to be minimal.

On the second point, we have some trouble reconciling this view with the picture of climate change in the Basin that we get from the scientific literature. In general, the logn-term changes in a given model move in tandem with increasing global average temperature: 2070 projections are generally an exaggerated version of 2040. (The latest report from the National Academy of Science, "Climate Stabilization Targets:
Emissions, Concentrations, and Impacts over Decades to Millenia" documents this principle).

**There are several reasons that we feel the 2070 results should be discussed in more detail:**

- **2070 streamflow may differ from 2040 streamflow for other basins besides the Colorado above Glenwood Springs**. For example, in the San Juan River basin, models indicate more warming *and* less precipitation in 2070 than in 2040. Therefore this basin would probably see larger hydrologic impacts in 2070 than in 2040. This comparison should be shown.

- **Modeled crop demand is likely to be larger in 2070 than 2040** due to the warmer temperatures and even longer growing season than 2040. This factor warrants more discussion.

- **Streamflow timing is likely to be different in 2070 compared to 2040** due to the increased temperatures.

**Interpretation of the climate change scenarios**

Several points related to the interpretation of the climate change scenarios.

- **These scenarios consist of a range of "plausible futures" that are consistent with the modeling assumptions.** It is not appropriate to assign exact probabilities, or equal probabilities, to these scenarios. The text of Table 1 it states "Each of the selected climate projections is equally probable; but differs from the others." This is incorrect. Each of the selected projection has an unknown probability, but it is a plausible future consistent with the modeling assumptions.

- **The large range in projected streamflow in the CRWAS scenarios and in the Reclamation runs (Figs 2-10 to 2-13) is not entirely due to climate change, but is partly a result of natural variation in precipitation.** This is true for both the wet and dry extremes. We recommend that this caution be noted in the report and that future work be directed to using or developing methods that can better differentiate between trends and natural variability in precipitation. Note that this is not a significant problem for temperature, where the natural variability is small compared to the projected trends.

- **The cumulative distribution functions (CDFs; Figs 2-10 to 2-13) are hard to read and interpret.** While these provide essential context for the scenarios chosen, more explanation is warranted. In particular, what are the mean and median flow changes for the full distribution? What does this graph look like for the San Juan basin, which is likely to be drier?

- **The study pools all emissions scenarios when considering climate change.** This will have only a modest effect for the 2040 projections, as the range of temperature and precipitation projections for the three emissions scenarios overlap considerably. However this will have a significant effect for the 2070 projections, where temperature changes are much larger for the A2 scenario than for the B1 scenario. The reason for pooling all the scenarios together should be clearly stated as well as the scientific result that the magnitude of future climate change is *contingent* on future emissions. This basic fact of climate science should be noted in the report.

- **Recent research on the effect of dust on the timing of runoff shows that it can lead to air temperature being a less important factor in snowmelt.** Recommendations for future modeling should include incorporating recent dust levels in their calculation. (It is unclear what assumptions were made about dust/snow-albedo for this study or whether the snow model was calibrated against recent runoff to account for this effect).

- **The executive summary does not address reliability of supply**. However, the "low flow intensity duration" analysis (for example, page 3-3) addresses this question to some extent, and these results should be mentioned in the executive summary. We encourage the use of the sets of "resequenced" hydrologies developed in this study to help assess the reliability of future supply as a part of Phase II of the study.

- **The discussion of sources of uncertainties** (page VII) states "the inherent uncertainties in the available global climate models in projecting the magnitude and nature of greenhouse gas emissions". This should read "the inherent uncertainties in projecting the magnitude and nature of greenhouse gas emissions." as the projections are not done by the climate models. The discussion of uncertainty should also mention "bias correction of climate model output" as well as "uncertainty in hydrologic models processes and parameters" as potentially large factors.