

A. Title: Reconciling Projections of Future Colorado River Stream Flow

B. PIs: Nick Graham (HRC)/Dan Cayan (CAP), Dennis Lettenmaier/Andy Wood (CIG).
Robert Webb/Martin Hoerling (WWA), Jonathan Overpeck/Holly Hartman (CLIMAS)

C. Funding Justification:

CAP/HRC to support hydrologic modeling, diagnosis, and provide support for Graham to provide leadership and coordination for the intercomparison project and to summarize findings; **CIG** to support hydrologic modeling and diagnosis; **WWA** to support modeling diagnosis; **CLIMAS** to support an evaluation of the usefulness of the intercomparison process and exploration of new ways to present projections of future climate and associated drought impacts to meet policy development and decision-making needs;

Meeting/Travel: support for two meetings: a smaller meeting to develop a consensus intercomparison plan that will meet stakeholder needs, and a larger meeting at the end of the project to present intercomparison findings to policy and decision makers [In addition to RISA participants, J. Prairie (USBR), C. Milly (GFDL/USGS), L. E. Hay (USGS), K. Werner (NWS CPRFC), Eric Wood, (Princeton), T. Pagano (NRCS), and Kosta Georgakakos (HRC) will be invited to participate in this intercomparison].

D. Project duration – 12 Months

E. Project description:

A drought information system must convey to policy and decision maker the nature of the uncertainties associated with the material being provided. Users are particularly challenged when they cannot reconcile what appear to be disparate research findings. When confronted with this situation, the critical issue to be resolved for users is how much of the range of results reflects actual uncertainty with associated risks and how much is due to different methodological approaches and model biases. Within the Upper Colorado River Basin, reductions in naturalized flow by the mid 21st century have been projected to be ~45% by Hoerling and Eischeid (2007), 10 to 25% by Milly et al (2005), ~18% by Christensen et al. (2004), and ~6% by Christensen and Lettenmaier (2007). The recent Seager et al (2007) analysis of future P-E (a proxy for runoff) suggests an "imminent transition to a more arid climate in southwestern North America". While the range of projections may be of intellectual interest and stimulate scientific debate, to users and decision makers at the federal level, in the seven basin states, and internationally, providing what appears to be conflicting information on future conditions is a serious impediment to drought and climate change planning. The results of the intercomparison will be readily applicable to address the needs of water planners elsewhere, especially across parts of the western U.S. and other middle latitude continental settings where water resources are heavily dependent on snowmelt runoff from mountainous headwater areas.

Water Year	Inflow to Powell (% of Average)	Powell and Mead % Capacity
1999	109%	95%
2000	62%	86%
2001	59%	78%
2002	25%	63%
2003	52%	55%
2004	51%	46%
2005	105%	54%
2006	72%	51%
2007	~50%	?
Average 1999-2006	67%	66%

Table 1. Nine recent years of estimated natural flows for the Upper Colorado River Basin and the percent capacity of Lake Mead and Lake Powell. (Courtesy of T. Fulp, USBR)

A number of stakeholder and users have begun to ask if the past decade of runoff patterns and streamflows levels in the upper Colorado River Basin are harbingers of the future (see Table 1). Furthermore, some of the first questions often asked by users and stakeholders when presented with future projections are: How well do these methodologies and models reproduce the recent past departures from long term averages? What was the primary cause of these departures? and Will similar conditions occur more frequently in the future? To address these questions and understand the sensitivity of the basin to future changes in the mean and seasonality of temperature and precipitation, we propose an intercomparison project to systematically evaluate the various methodologies and models being used in projections of future streamflow and to

understand why different modeling approaches produce such different levels of flow reduction. We will also identify a common subset of appropriate climate scenarios and models to use when developing future projections of streamflow, and to produce an internally consistent suite of projections of Colorado River streamflow and overall hydrologic state of the basin for mid to late 21st century decades.

Methodology

Individual water years since 1995 cover a wide range of seasonal evolutions of climate and resulting Colorado River stream flow due to shifts in the average and seasonality of temperature and precipitation, snow pack development and decline, and antecedent soil moisture conditions. The proposed intercomparison methodology will involve running the models used to estimate future Colorado River stream flows retrospectively to see how well they simulated observed changes in stream flow to known changes in temperature and precipitation for Water Years 1995 to 2007. To partition the sensitivity of the methodological approaches and models to changes in temperature and precipitation, 24 retrospective simulations will be made where the observed input values for temperature and then for precipitation (e.g., hourly, daily, monthly) for individual years are replaced with long term climatological averages for an agreed upon span of years (e.g., 1970-1999). Simulations focused on elevation sensitivity will examine the hydrologic implications of significant spatial heterogeneity of snowfall in the basin and the fact that the resulting runoff is derived mostly from relatively small, high altitude headwater drainage areas. Sensitivity experiments will be used to determine the extent that negative feedbacks in the hydrologic system can offset expected reductions in streamflow due to warmer temperatures (e.g., earlier runoff during warm winters is associated with reduced evapotranspiration in late spring and summer). We will use IPCC AR4 climate model projections for multiple emission (SRES) scenarios as input to simulate Colorado River flows and the hydrologic status of the basin for 2050-2060 and 2090-2100. Finally, we will work with stakeholders to assess the best ways to communicate the range of possible future hydrologic change in the Colorado River Basin.

Description of deliverables

- An intercomparison of methodological approaches and models used to generate estimates of mid-21st century stream flow in the Colorado River Basin to assess how much of the range of results reflects actual uncertainty with associated risks and how much is due to different methodological approaches and model biases.
- Because snowmelt processes are crucial in generating runoff in key parts of the basin, an evaluation of the performance of the different methodologies in selected snow-dominated and rainfall dominated sub-basins will be carried out.
- Identification of an appropriate subset of climate scenarios and models to develop estimates of future climate and drought impacts in the southwestern US
- An exploration of ways to present projections of future climate and associated drought impacts to stakeholders
- An evaluation of the usefulness and usability of the scientific intercomparison process to meet policy development and decision making needs for coping with drought issues.
- An initial step toward informing an improved observation system to monitor drought in the Colorado River basin (e.g., we may conclude that soil moisture, runoff timing etc may be key elements that should be added to routine monitoring and drought reporting network).

F. Relevance to NIDIS:

This project will help advance NIDIS goals for an enhanced drought preparedness and early warning system through science-based decision-support system that provides information related to drought and water-sensitive impacts to the public and decision-makers. The work will support the expected establishment of a NIDIS Pilot Project in the Colorado River Basin through a systematic assessment of sensitivity of the basin to future possible climate change that is needed to explore drought risk reduction strategies in partnership with users and federal, state, regional and local agencies

G. Federal Interagency: USDA/NRCS, DOI/USBR/USGS, NOAA/GFDL, Seven Basin States, WGA