

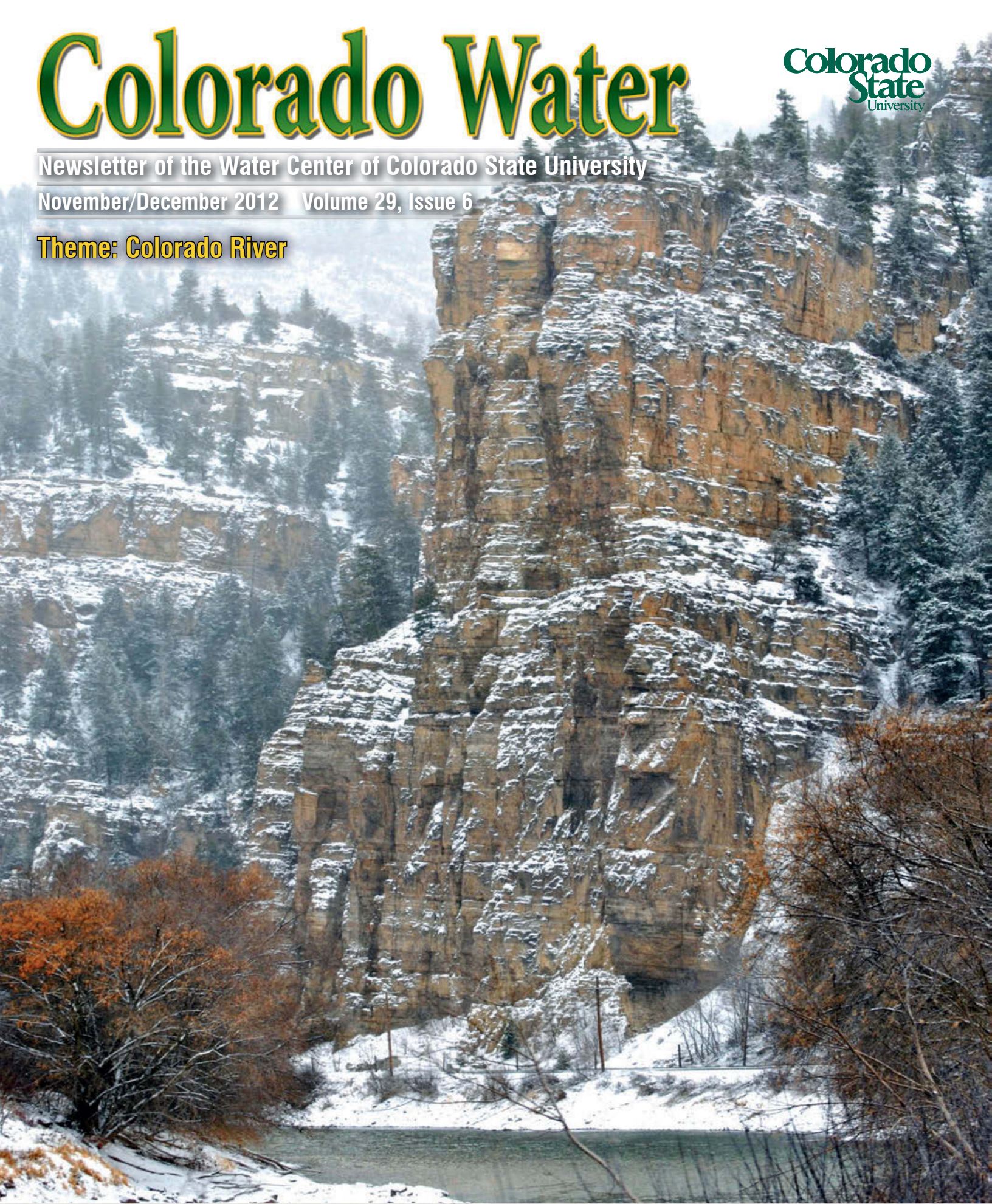
# Colorado Water

Colorado  
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**Theme: Colorado River**



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Front Cover: The Colorado River flows through Glenwood Canyon. Photo by Steve Wilson

This Page: Photo by Alina Rogers

# Editorial

by Reagan Waskom, Director, Colorado Water Institute

The Colorado is a grand river, and was thusly named until 1921 when Congressman Ed Taylor established our state as the headwaters through the simple act of renaming the Grand River. The following year, Greeley lawyer Delph Carpenter helped craft and negotiate the 1922 Compact, providing Colorado time and certainty to develop its share of the river. Through this same period, the intrastate tug-of-war to develop transbasin diversions for East Slope cities and farms shaped much of Colorado's institutional water history. It is indeed a grand story that captures the interest of water scholars across the globe.

2012 was another fascinating year on the Colorado River. We celebrated "The Year of Water" in 2012, while the drought expanded north and westward from the San Luis and Arkansas Valleys. We awaited the outcome of the Windy Gap and Moffat Firming environmental impact statements and the global settlement negotiations between Front Range and West Slope water interests. At the same time, Colorado negotiators continued to work with downstream states and Mexico to craft a new international agreement for dealing with both water surpluses and shortages. These events may just provide interesting news stories for the general public, but of course a great deal is at stake for our future and the entire Southwest. Coloradans have benefited from a legacy of leadership for Colorado River management and governance, and this continues today with strong and visionary leaders.

The most recent news on the river is the release of the Colorado River Basin Water Supply and Demand Study (also known as the Basin Study) conducted by the Bureau of Reclamation and the seven basin states. To almost no one's surprise, it projects that within 50 years, demand will outstrip supply, perhaps by as much as 3.2 million acre feet (MAF). To some, this confirms that the Colorado River is already fully allocated, while others see this as confirmation that Colorado must get busy developing the remaining portion of its 51.75 percent of the Upper Basin's share, however much water that might actually be. Our ability to store almost 60 MAF, or nearly four years of average natural flow of the river, confirms the foresight of our predecessors, while environmental voices remind us of what can be lost.

The Basin Study reviewed almost 150 options for dealing with future supply shortfalls, ranging from very costly options such as desalination and transbasin pipelines, to the dry-up of agriculture—the sector that stands to lose



the most water unless proactive steps are taken. Clearly, no single option will be sufficient to resolve future projected supply and demand imbalances and uncertainties.

Planners aspire to certainty; water providers even more so. Yet, water managers must expect future surprises and the persistence of uncertainty. In the arid West, the one perennial certainty is that we will never have enough water for all of the human and environmental needs, particularly with the overlay of growth, energy development, and the inevitability of drought. Studies of future demand always seem to rely on projecting current trends, and while a reasonable starting place, this might explain why Malthusian logic rarely pans out. The looming uncertainty is how future climate may affect water supply and whether new institutional arrangements and technology can meet the challenge by increasing efficiency and development of new supplies.

This issue of Colorado Water newsletter features just a few of the current academic studies underway on the Colorado River and some of the recently completed historical works and celebrations. The importance of this river not just to our future, but also to our current water story will continue to unfold in 2013. Locally, the critical importance of the Colorado-Big Thompson project is witnessed as water providers struggle with the aftermath of a burned Poudre River Basin and the reliance on transbasin Colorado River water to meet municipal demand. This grand river provides rich lessons and research questions for our students (and our future water managers) to grapple with in order to better understand the complexities of 21st century river basin management.

# Paleohydrology of the Lower Colorado River Basin and Implications for Water Supply Availability

Jeff Lukas, Western Water Assessment, University of Colorado

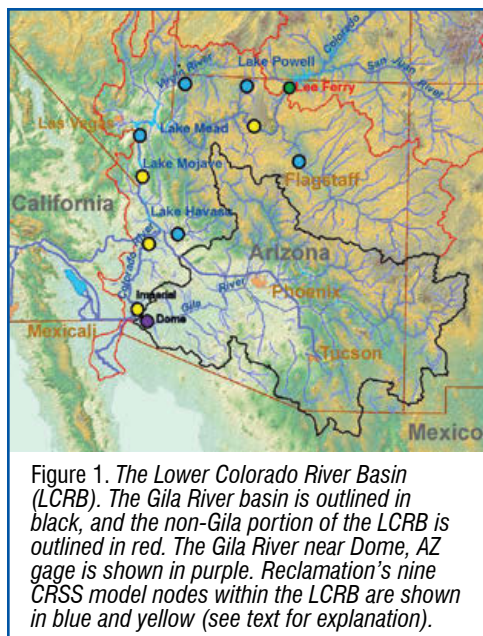
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## Introduction

As the annual demand on the Colorado River system approaches the annual supply, the contribution from the Lower Colorado River Basin (LCRB)—on average about 15 percent of total system flows—becomes more critical. In fall 2010, our research team began a project to develop new paleo-reconstructions of LCRB hydrologic variability from tree-ring records, and incorporate them into an assessment of water supply risk for the Colorado River Basin. This project was primarily motivated by the interests of the Colorado River District, which is responsible for the conservation, use, protection, and development of Colorado's apportionment of the Colorado River. The project was carried out with funding from the Colorado Water Institute, the Colorado River District, the Western Water Assessment, and graduate student support from the Department of Civil and Environmental Engineering, University of Colorado.

The general framework of the project was to (1) develop naturalized flow records for the Gila and non-Gila subbasins of the LCRB (Figure 1); (2) compile existing tree-ring data for the LCRB (described in the April 2011 article); (3) generate tree-ring reconstructions of streamflow using multiple methods; and (4) use the reconstructions to inform improved system risk modeling of the entire Colorado River Basin. A previous article for Colorado Water (April 2011) described in some detail the context, objectives, and methods of



the project, so we will not repeat that information here.

## Results

The results for the main components of the project are described below.

*Analyses of gaged flows in the LCRB and development or selection of naturalized annual flow records for the historic period (~1906 to present) to use as targets for the paleohydrologic reconstructions for these two locations:*

- *The flow for the Gila River near its confluence with the Colorado*
- *The intervening flow on the Colorado River between Lee Ferry and Imperial Dam*

The hydrology of the Gila River is almost entirely modified by reservoir operations and depletions before it joins the Colorado River, and these modifications began in the

first decade of the 1900s (Figure 2). Several headwater gages on the mainstem Gila and its major tributaries (Salt River, Verde River, Tonto Creek) are above the dams, and most diversions and remain mainly natural (Figure 2). In 1946, the Bureau of Reclamation developed estimates of natural flow at gages downstream of the dams and diversions, including Dome, Arizona (the closest gage to the mouth), for the period 1897–1943. After extensive analysis of the gaged records for the Gila River Basin, we developed a local polynomial regression model between the Bureau of Reclamation-estimated naturalized flow at Dome for the 1897–1943 period and the near-natural gaged flows at the headwater gages. The modeled estimated natural flows for the Gila near Dome cover the period 1915–2010. We also retained the gaged flows at Dome as a calibration series since they represent the inputs to the Colorado from the Gila under current managed conditions and are more relevant for the system risk modeling as we implemented it.

The naturalized intervening flow on the Colorado River between Lee Ferry and Imperial Dam proved to be an elusive quantity. Reclamation maintains a natural flow dataset of the Colorado River and major tributaries (see Figure 1) for the 29 input nodes for their Colorado River Simulation System (CRSS) model, but for the nine nodes in the LCRB, these flows have not been explicitly naturalized, and some may contain artifacts of the water-balance modeling used to reconcile the total flows entering the

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top of the LCRB with those gaged at the bottom (Imperial Dam). In fact, we discovered that of the nine LCRB nodes, flows from 1906–2008 at five of the nodes (shown in blue in Figure 1) were well-correlated with observed precipitation and streamflow in adjacent basins, while the flows at the other four nodes (shown in yellow) were essentially uncorrelated with observed hydroclimate. We found also that the total flows at the five “good” nodes were well-correlated with flows simulated by Reclamation using the VIC hydrology model. Thus, we retained only the flows at the five good nodes to represent the Lee Ferry to Imperial reach, for calibration with the tree-ring data, recognizing that the magnitudes of the total flow at all nine nodes will require further investigation. Reclamation engineers have indicated to us that as a followup to the Colorado River Basin Study, they will revisit their natural flows data for the LCRB.

*Generation and evaluation of tree-ring reconstructions for Gila flows and the mainstem intervening flows using multiple methods*

Tree-ring paleohydrologic reconstructions have been generated using many different statistical approaches, all of which have particular strengths and weaknesses. The most common approach has been multiple linear regression (MLR); thus, to establish a baseline for comparison with new approaches, we used two variants of forward-stepwise MLR, with and without Principal Components Analysis (PCA). We also used Lowess regression, which uses a smoothed-and-fitted-curve relationship instead of a linear relationship, and a recently-developed non-parametric K-nearest-neighbors (K-NN) method.

We also implemented two new statistical methods for tree-ring reconstruction of streamflow. For the first method, Local Poly, we employed

a cluster analysis on our regional network of tree-ring chronologies to identify spatially coherent subregions that have a common climate signal, then performed PCA on the clusters to obtain the main modes of variability. The main modes are used as predictors in a local polynomial model, within a Generalized Linear Model (GLM) framework, fit to the observed natural streamflows. This approach is similar to the K-NN resampling method but has the ability to produce flows beyond the range of the observed data while also capturing non-linearities. The second method introduces the extreme value analysis (EVA) peaks-over-threshold (POT) method to tree-ring reconstructions of streamflow. The EVA-POT models the probability of threshold exceedance, and the magnitude of exceedances, and is especially suited for reconstructing intermittent streamflow, such the gaged flows at the mouth of the Gila River.

The tree-ring reconstructions of Gila River natural flows using five different methods explain between 41 percent and 61 percent of the variance, respectively, in the observed flows. They all capture the low flows better than the high flows, as is typical for tree-ring reconstructions, and they track each other very well both during the observed period (Figure 2) and the longer

paleo-period (Figure 3), testifying that the underlying tree-ring information is robust to the statistical method used. The Local Poly and Lowess methods are able to express larger magnitudes in high-flow years than the MLR reconstructions. Across the methods, mean reconstructed flows are generally lower before 1900 than after 1900, and the 20th century also appears to be anomalous compared to preceding three centuries in having two multidecadal wet periods. We used three methods to reconstruct the mainstem Colorado River intervening flow, with lower explained variance (37 percent–52 percent) than with the Gila, probably reflecting the aforementioned issues with the observed natural flow record used to calibrate the reconstructions. As with the Gila, the mainstem low flows are reconstructed more accurately than the high flows.

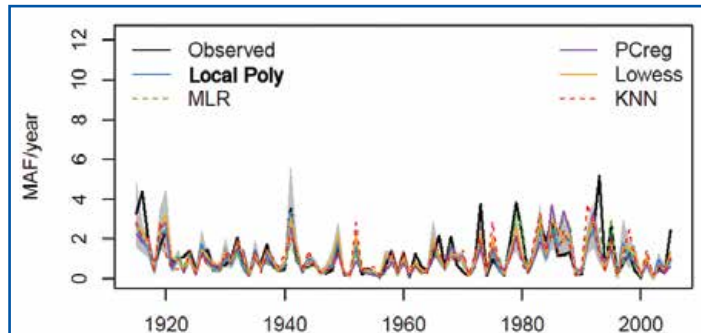


Figure 2. Five different methods for tree-ring reconstruction of natural annual streamflows (1915–2005; colored lines) for the Gila River near Dome, AZ, compared with the estimated natural streamflows (“Observed”). The “Local Poly” model (blue line) also has gray shading showing the five and 95 percent confidence intervals around that reconstruction.

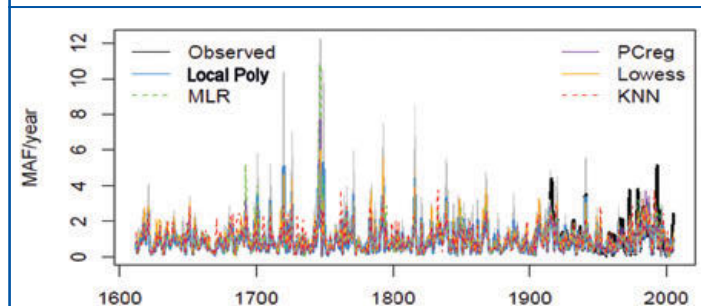


Figure 3. Same as Figure 2, but showing the full common length (1612–2005) of the five tree-ring reconstructions of natural flows for the Gila River near Dome, AZ. Note that the reconstructions show several annual flows higher than any observed flow, and that the 1900s were unusual in having two sustained wet periods.

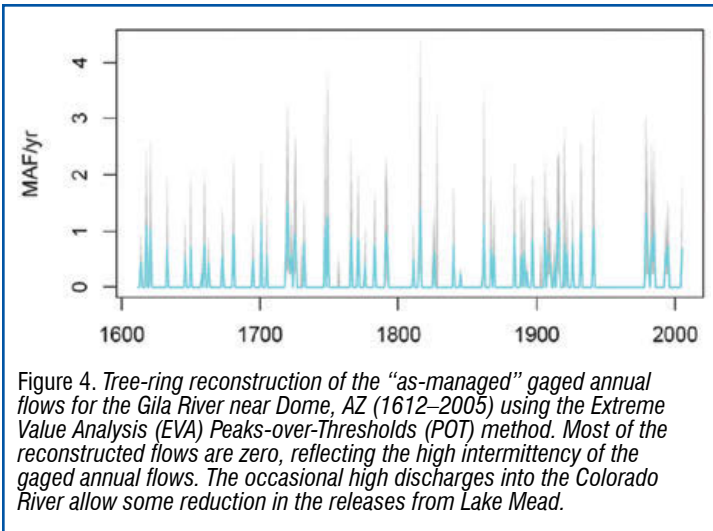


Figure 4. Tree-ring reconstruction of the “as-managed” gaged annual flows for the Gila River near Dome, AZ (1612–2005) using the Extreme Value Analysis (EVA) Peaks-over-Thresholds (POT) method. Most of the reconstructed flows are zero, reflecting the high intermittency of the gaged annual flows. The occasional high discharges into the Colorado River allow some reduction in the releases from Lake Mead.

The EVA reconstruction of the gaged Gila River flow shows that highly intermittent annual flow series, with above-zero flows in less than half of all years, can be effectively reconstructed using tree rings (Figure 4). Note the dense cluster of high flows in the early 20th century compared to the preceding 300 years. In total, these new reconstructions for the LCRB also demonstrate that long-term hydrologic variability in the LCRB is different enough from the variability in the Upper Colorado River Basin to justify including the former in system risk assessment as a complement to the latter.

*Performed system response analysis using the new LCRB reconstructions as input to a modification of the Rajagopalan et al. water-balance “bathtub” model of the Colorado River Basin*

The water-balance model is simple yet representative of the water resources system in the basin, and has been previously used to investigate the risk of active system storage (60 million acre-feet; MAF) being depleted under different scenarios. For this project, the model setup was modified to so that variability in LCRB flow was consistent with the new paleo-reconstructions, and so that periodic inflows from the Gila River could serve to reduce the releases needed from Lake Mead. As in a previous

study, the water-balance model was driven by natural variability alone and with two climate change scenarios (progressive flow reductions), under two different reservoir operation rules and demand management

alternatives, for a total of 12 scenarios.

We found that the periodic Gila River discharges do provide measurable mitigation of water supply risk. They reduce the Colorado River system risk slightly under all scenarios. Figure 5 shows the evolution of cumulative probability of storage depletion by 2057 for four of the 12 scenarios, and the difference when each scenario is run with and without the Gila River inflows. Furthermore, including the Gila reduces the average shortage volume per year, increases the storage volume in the system, and reduces the average number of shortages. An important caveat is that the modeling assumed that 100 percent of the Gila

River inflows (up to 1.5 MAF/year, the delivery obligation to Mexico) can be used to reduce Lake Mead releases. In practice, due to flow timing and water quality issues, the substitution achieved has been much less than 100 percent. But the modeling result points to the potential for more deliberate management of Gila inflows to reduce system risk.

**Summary**

The project was successful in its objectives of (1) robustly representing the long-term hydrologic variability of the LCRB using multiple statistical methods, including two promising new approaches, and (2) incorporating that variability into Colorado River Basin system risk modeling. We have found that the variability of LCRB flows does matter to the system, and that in particular the Gila River can have a measurable impact on system risk due to its periodic, significant discharges into the mainstem. Potential follow-up work could be focused two different tracks: improving the estimates of natural flows for both the Gila and the LCRB mainstem, and investigating the feasibility of actively managing Gila River inflows for risk reduction.

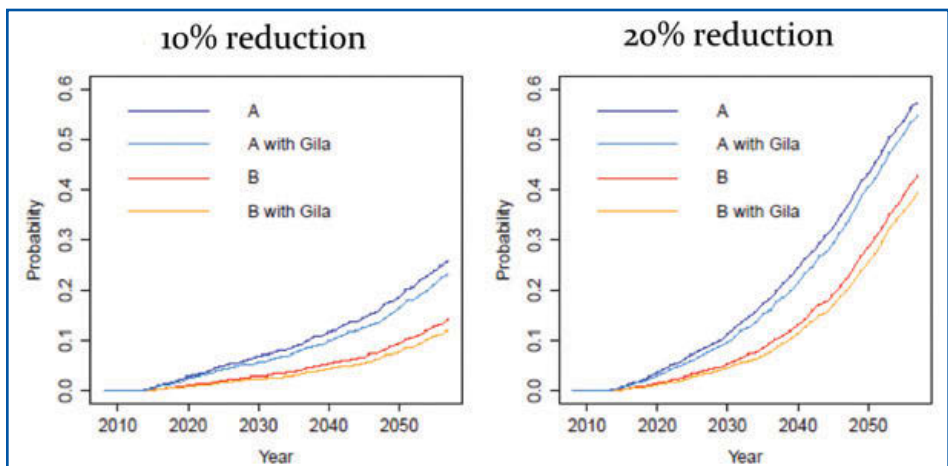


Figure 5. Probability of depletion of aggregate Colorado River Basin system storage, as modeled under four scenarios: reduction in flows of 10 percent (left panel) or 20 percent (right panel) by 2057 due to climate change; (A) the current (2007) policy for implementing Lower Basin shortages or (B) a more aggressive policy for implementing shortages; and (all scenarios) basin demands increasing per Reclamation projections from the 2007 EIS. Each scenario was then run with and without periodic Gila inflows. In all four scenarios, the Gila inflows measurably reduce overall system risk.

# Mapping Irrigated Agriculture in the Colorado River Basin

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The Geospatial Centroid at Colorado State University (CSU) ([gis.colostate.edu](http://gis.colostate.edu)) was funded by The Nature Conservancy (TNC) to develop a geospatial database of existing irrigated agriculture in the Colorado River Basin (CRB). The CRB includes 246,000 square miles that produce 15 percent of the nation's crops from approximately 1.8 million acres of irrigated agriculture—a key component of consumptive use. This project has run in parallel with other CRB projects. The Environmental Defense Fund funded the Agricultural Water Governance Mapping project, and the U.S. Department of Agriculture funded a research project on agricultural water, both of which are described in this issue. We are exploring ways to integrate the entire suite of publicly available data collected from these projects into a singular dataset with the long term aim of delivering the data online. Such a dataset is unique in that data from multiple sources (i.e., U.S. Bureau of Reclamation [USBR], U.S. Geological Survey [USGS], National Agricultural Statistics Service, and agricultural water supply organizations of all basin states) and multiple themes, such as governance, agricultural lands, and hydrology, will be collected and organized to create a value-added dataset of the CRB.

The objective for the TNC project was to create comprehensive spatial coverage depicting the extent of irrigated agriculture, to uniformly map irrigated crops using existing data from the USBR, and to identify gaps in the spatial data. The database produced for this report juxtaposes the extent of irrigated agriculture across the landscape with the size and extent of the entire CRB.

Table 1. Existing data collected for CRB Irrigated Agriculture mapping. Refer to *Demonstration Mapping for Increasing Agricultural Water Security across the Colorado River Basin, January 2012*, prepared for The Nature Conservancy by Ownby and Laituri for metadata.

Data	Source	Year
Upper Colorado River Basin Consumptive Use and Loss Data: Irrigation by Status and Type <sup>1</sup>	Bureau of Reclamation	Five year reporting cycles: 1990 – 1995 <sup>2</sup> 1996 – 2000 2001 – 2005
Irrigated Parcels from Division 4 (Gunnison), Division 5 (Colorado), Division 6 (Yampa/White), Division 7 (San Juan/Dolores)	Colorado Decision Support System	2005
Lower Colorado River Basin Consumptive Use and Loss Data: Crops (by season) <sup>3</sup>	Bureau of Reclamation	2005
Cropland Data Layer <sup>4</sup>	USDA - NASS	2010
Salinity Control Projects (Colorado only)	Bureau of Reclamation	2009
Salinity thresholds Irrigated Agriculture	SPARROW <sup>5</sup>	2009
303d listed streams	Environmental Protection Agency	2008
Selenium Areas <sup>6</sup>	USGS	1999

<sup>1</sup> Irrigation is mapped according to status or type in the UCRB. Status refers to lands that are fallow or irrigated. Irrigation type refers to general type: flood, sprinkler, or unknown. The BoR has generated or obtained new irrigated crop acreage estimates for all UCRB states for at least one year within each 5-year reporting period.

<sup>2</sup> The 1990-1995 irrigated crop layer was an early effort to map irrigation using a consistent methodology across the UCRB. Since then, BoR has produced crop maps of only portions of the UCRB that have not been mapped by their respective states.

<sup>3</sup> The Lower Colorado River Accounting System (LCRAS) is used to inform the CUL reports and was developed to refine estimates of agricultural consumptive use, based on ET and water balance. A GIS database is developed from the processing and interpretation of remotely sensed data. In addition, BoR collects ground reference survey data for approximately 12% of irrigated fields in study area, selecting survey sites in each major irrigated area.

<sup>4</sup> The CDL does not include irrigation or seasonal information explicitly.

<sup>5</sup> The 2009 dissolved-solids SPARROW (Spatially Referenced Regressions on Watershed Attributes) model was developed for the Upper CRB as a spatially explicit estimation of salinity loading. The current SPARROW model uses the 1991 climate year and the BoR 1990-1995 extent of irrigated lands layer.

<sup>6</sup> Selenium pollution data are from the USGS report – Areas Susceptible to Irrigation-Induced Selenium Contamination of Water and Biota in the Western United States.

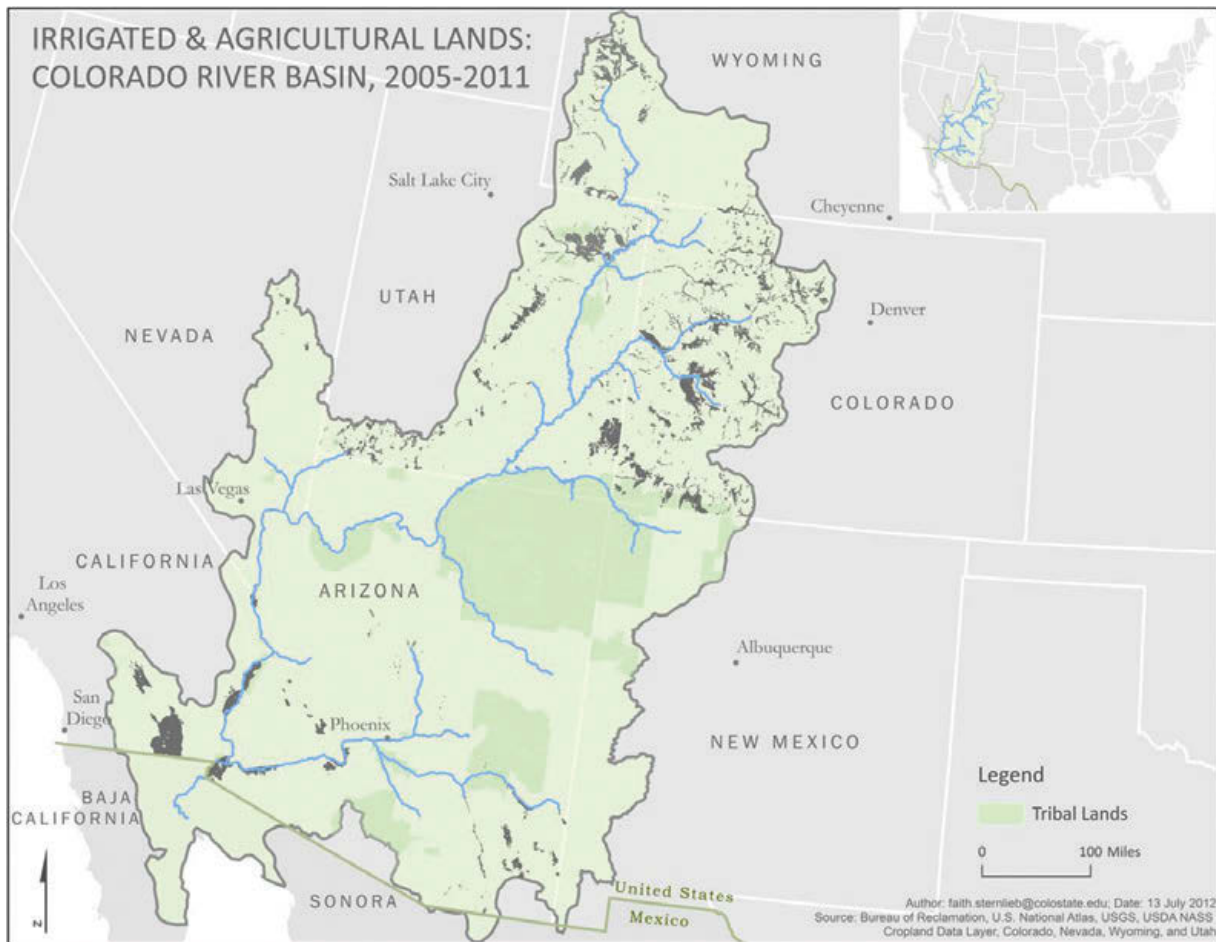


Figure 1. Irrigated and agricultural lands of CRB, including the extent of both irrigated and dryland agriculture based on additional data collected from 2011.

The database is made up of the following data derived from multiple sources. Base layers downloaded from the National Atlas include the Colorado River and its tributaries, the USBR management boundary, the boundary between the Upper and Lower Colorado river basins, state and county boundaries, and eight digit hydrologic units obtained from the USGS National Water Information System. A spatial and temporal database (Table 1) was created of digital data (1990-2005) provided by the USBR using the Consumptive Uses and Losses Reports (CULRs) in the Upper Colorado River Basin (UCRB). Spatial data were also provided by the USBR of irrigation for the lower main stem of the Colorado River. These data layers were compared with other data from USDA—Cropland Data Layer (CDL) and data from the Colorado Water Conservation Board’s Colorado Decision Support System (CDSS). Additionally, USGS salinity

and USBR selenium data for the Upper Colorado River Basin (UCRB) were examined. The EPA’s 303d listed streams were also incorporated into the database.

The products created from this research include both a query-able ArcGIS geodatabase and an interactive set of PDF maps. In May, a workshop at CSU utilized the projection-based Google Liquid Galaxy (<http://lib.colostate.edu/services/computers/google-liquid-galaxy>) to present the results to TNC, USGS, the Environmental Defense Fund, and CSU. Since completion of this project, additional agricultural information has been added that encompasses dryland agriculture across the entire basin, including irrigated agricultural lands (Figure 1).

There were several challenges associated with the development of this dataset. The USBR does not create maps of irrigated agriculture as part of

their CULRs in either the Upper or Lower Basins. Rather, the spatial information about irrigated agriculture is used in analysis to inform the accounting for consumptive use, presented in tabular format. Creating spatial products from the USBR data is inherently imperfect as these data are a snapshot in time, where often further accounting metrics are assigned to determine the areal extent of

irrigated agriculture from other data sources (i.e., Census of Agriculture) for an output that is not spatial but tabular. Additionally, the USBR’s accounting of irrigated agriculture is an estimation built upon best available data collected from a variety of sources. In constructing this dataset, the data were stitched together across the entire CRB and amalgamated and standardized to present a holistic snapshot of the CRB.

USBR methods of data collection for the CULR are different for the Upper and Lower basins. In the Upper Basin, states estimate their consumptive uses and losses of CRB water using methods different from those used by the USBR and between states, so estimates may differ between entities. The CULR use USBR methodologies to estimate consumptive uses and losses based on the modified Blaney Criddle method for all Upper Basin states with the exception of New Mexico. The



USBR uses a process to further refine their statistics on irrigated agriculture in which data are collected from the USDA Census of Agriculture (COA) that is conducted every five years and state's annual County Agricultural Statistics (CAS). In the Lower Basin, the USBR accounts for use on the main stem using a "diversion minus flow" methodology for all water users within the Lower Basin states, as published in Water Accounting Reports and the CULR. Until 2000, the CULR included irrigated acreage and estimated consumptive use and losses in the Lower Basin tributaries. The USBR recognizes that there are discrepancies

between the various accounting approaches and are seeking to resolve these discrepancies in both the Upper and Lower basins.

To map irrigated agriculture, a common crop type classification was developed to map crop types across the entire basin and to compare against the crop types from the CDL and CDSS. This Common Classification was adapted from the classification procedures developed for the South Platte Decision Support System in Colorado (Table 2). Without the Common Classification, crop types would be classified differently between the Upper and Lower Basins. The data were reclassified

to represent consistency of crop types across the basin, and assumptions have been made in re-categorizing data. For example, the original CDL classification included 91 different crop types within the basin that were reclassified for this project by aggregation (such as pasture, hay) or exclusion (such as dryland agricultural crops; crops not found in the CRB) into the 10 crop types of the Common Classification System.

Changes are underway with respect to mapping the CRB irrigated lands. For example, the USGS is developing a spatial dataset from the mid to late 2000s of irrigation for the Upper CRB. This mapping will be used to improve the outputs from the SPARROW model, will refine the extent of irrigation in the Upper CRB by status and type, and will be used as a baseline for monitoring change in salinity loading from irrigation. Also, the USBR is working on changing procedures for estimating evapotranspiration in the UCRB from crop maps combined with surface weather information to remote sensing-based energy balance models for 2006-2010. However, relationships between crop types will need to be made explicit to estimate consumptive water used by agriculture.

Collection of agricultural data for the CRB has continued after the completion of the TNC project. Efforts to include recent, available data from various entities are essential to creating a current and holistic database of the CRB. Governmental organizations in partnership with universities are developing classification techniques utilizing remotely sensed data with the long term aim of creating real-time representation of irrigated agriculture in the CRB. If you are interested in learning more or would like to include your data in the CRB database, please contact Melinda Laituri, [melinda.laituri@colostate.edu](mailto:melinda.laituri@colostate.edu).

Table 2. Common Crop Classification used for the CRB. adapted from Schneider, Martin, and Woodward, 2006, SPDSS Memorandum 89.2 – Crop and Land Use Classification Procedures for Year 2001.

Crop	Characteristics
Alfalfa	A flowering plant cultivated as an important forage crop in Colorado. It usually greens up during April and early May and is harvested 3-4 times during the growing season that ends in early October.
Bluegrass/Sod	A lawn grass, which comprises less than 2% of total irrigated area in Water Divisions 4-7 in Colorado. Sod or turf is grass used to establish lawns. This comprises a negligible portion of the irrigated areas in Water Divisions 4-7 in Colorado.
Corn	Includes corn used for grain or silage. Planted between late April to early May and harvested from September through November. Includes sorghum and sudan.
Cotton	Cotton
Dry Beans	Includes pinto beans, white beans, and others. Planted between May to early June and harvested from late August to late September.
Grass Pastures	Includes pastures with cultivated grass and hay. It greens up in spring and early summer
Orchard	May include Ground Cover. Apples, peaches, plums, and grapes are the major crops grown in orchards in the region.
Small Grains	Includes winter wheat, spring wheat, oats, barley, rye, and millet. Winter wheat is planted in September of the previous year and is harvested around early July. Oats and barley are planted in March or early April and harvested in July.
Vegetables	Includes a variety of crops such as potatoes, squash, onions, pumpkins, lettuce, spinach, and broccoli.
Other	Includes everything else: Aquaculture, Blueberries, Camelinea, Clover/Wildflowers, Cranberries, Herbs, Hops, Mint, Other Crops, Rice, Sugarbeets, Sugarcane, Sunflower, Vetch.

# Mapping Agricultural Water Governance in the Colorado River Basin

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## Introduction

Emerging cooperative arrangements for water use, development, and conservation in the Colorado River Basin (CRB) indicate changes in both the political and environmental climate. These arrangements are geographically taking shape at the intersections of hydrologic, political, and social boundaries. Water agencies and organizations (e.g. private/public, national/local, governmental/non-governmental, etc.) are struggling with ways to address these complexities and, as a result, are creating new rules and arrangements that necessitate new datasets and visualization techniques. Agricultural (Ag) water supply organizations are central actors in new arrangements because they hold 70-80 percent of the water rights. In order to better understand these new rules and arrangements and how they affect Ag water supply organizations, the development of a geospatial database will facilitate the analysis of linkages between sectors and political jurisdictions at multiple scales that intersect with hydrologic adaptations throughout the basin. These intersections will identify locations where strategic arrangements with Ag already exist and where new arrangements may flourish.

This paper describes the process, evolution, and continued development of a basin-wide geospatial database describing agricultural water governance (complimentary to the project “Addressing Water for Agriculture in the Colorado River Basin,” this issue). For the purposes of this article, Ag water governance is the interface between Ag, hydrological, and human systems where formal and informal policies, rules, and

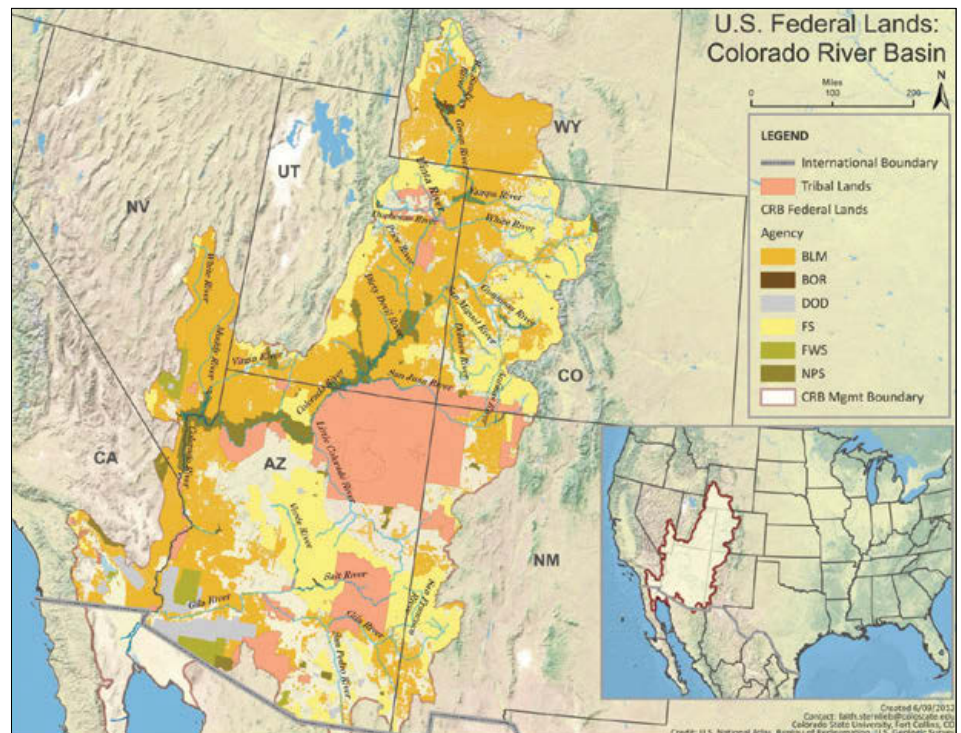


Figure 1. This map layout demonstrates U.S. Federal and Tribal Lands in the Colorado River Basin overlaid on a topographic basemap.

practices shape human interaction with the environment. The Colorado River Basin Agricultural Water Governance database is an effort to collect data about governance and heighten awareness about the changing circumstances of decision-making about water for Ag in the CRB. The aim of this project is to compile data for the entire CRB in one place to provide an online clearinghouse that will inform stakeholders, water users, and decision makers about Ag water in the basin.

## Geography

The CRB encompasses seven U.S. states (Arizona, California, Colorado, Nevada, New Mexico, Utah and Wyoming), two Mexican states (Baja California and Sonora), and at least 43 U.S. tribes (not including Mexican indigenous tribes). The Colorado River boundary in Figure 1 is defined by the

Bureau of Reclamation. The length of the Colorado River when measured from the Green River, Wyoming is 1,700 miles (2,736 km) long or 1,400 miles long when measured from Rocky Mountain National Park (43°09'13"N 109°40'18"W) to the mouth of the Gulf of California otherwise known as the Sea of Cortez (31°39'N 114°38'W). The drainage basin encompasses an area of 246,000 square miles (637,137.08 square km). The hydrology of the river is highly controlled through a series of dams and reservoirs which harnesses water for energy, consumptive, and non-consumptive purposes in the basin. Ninety percent of native in-stream flows originate from snowmelt of the Green (Wyoming), Gunnison and San Juan Rivers (Colorado). The current average flows are estimated at 14.7 million acre feet, and the total storage capacity is at 60 million acre feet. The majority of

Table 1. Federal agencies and their classifications under the Department of the Interior (DOI) that own and administer land in the Colorado River Basin: Bureau of Land Management (BLM), Bureau of Reclamation (BOR), Department of Defense (DOD), the Forest Service (FS), Fish and Wildlife Service (FWS), and the National Park Service (NPS).

DOI Agencies	Federal Lands Classification	Area in Miles <sup>2</sup>	% of Land in the CRB*
BLM	National Conservation Areas, National Monuments, National Recreational Areas, Public Domain Land, Wilderness, Wilderness Study Areas	82,920	34%
BOR		1,173	< 1%
DOD	Air Force, Army Corps of Engineers, Marine Corps, Navy	5,596	2.3%
FS	National Forests, National Recreation Areas, Wilderness, Wilderness Study Area	47,014	19%
FWS	National Wildlife Refuges, Wilderness	3,739	1.5%
NPS	National Historic Parks, National Historic Sites, National Memorials, National Monuments, National Parks, National Preserves, National Recreation Areas, Wilderness, Wilderness Study Areas	8,805	3.5%
	<b>TOTAL</b>	<b>149,247</b>	<b>60.8%</b>

\* These percentages are based on the Bureau of Reclamation Colorado River Basin management boundary, obtained from the BOR Lower Basin Office, which includes the Mexican portion of the basin. The area is estimated to encompass 246,000 mi<sup>2</sup>.

Table 2. Due to the complexity of overlapping jurisdictional boundaries in the Colorado River Basin, identifying boundary types and governance layers clarifies how decisions are made and who is affected by those decisions.

Boundary Type	Governance Layer	Description
Physical	Hydrologic Unit Code	Based on natural drainage systems defined by the National Hydrology Dataset (USGS)
	Hydrographic	Based on drainage basin delineated by each state and tribe
Administrative	Legislative	Based on federal, state and tribal laws and policies
	Judicial	Based on U.S. Federal, District and Appellate Court system
	Political	Based on governmental jurisdictions (federal, state, tribe, county, municipality, city)
Sector	Agricultural Water Supply Organization	Based on state statute and organizations' bylaws

outflows include trans-basin diversions (San Juan Chama, Central Utah Project, NCWCD/Big-Thompson, Colorado River Aqueduct/All American Canal, Fryingpan/Arkansas) and evaporation from major reservoirs.

The majority of land (60.8 percent) in the CRB is owned and administered by the U.S. federal government and under the jurisdiction of the Department of the Interior (DOI) of federal agencies (Figure 1, Table 1).

Tribal lands constitute 16 percent or 40,462 square miles (104,797 square km) of the CRB and are federal lands that are overseen by the Bureau of Indian Affairs (BIA) but administered independently as sovereign nations by the respective tribal governments. Although farmers and ranchers depend on the federal lands for grazing their livestock, all of the farming and Ag production takes place on the remaining private lands. The federal agency that has the largest presence in the CRB for water supply is the Bureau of Reclamation. In light of their water management responsibilities, the bureau holds the least amount of land (less than one percent).

## Geospatial Database Development

The geospatial database is currently under development. Much of the spatial data for the CRB is accessible online but is dispersed on the internet through various non-governmental organizations and governmental agencies. In addition, some of the data may or may not be available for download and/or viewed. Challenges in creating such a geodatabase include data collection and compilation from multiple sources (some of which are private and hold proprietary information) at multiple scales and for different purposes. Compounding the challenges are the different types of data such as satellite imagery, paper maps, historical records, and field data collection, as well as techniques used to collect data including global positioning systems, surveying instruments, and photogrammetry, among others. Finally, data collection at a coarse versus fine resolution, disparate standards for metadata, and minimal coordination in data collection efforts make it difficult to mainstream datasets.

The spatial data is organized in “governance layers” which describe physical and administrative jurisdictions as well as jurisdictions

that are socially and/or hydrologically organized. Governance layers are defined by two key components: 1) mandated or naturally occurring geographic boundaries and 2) decisions made based on those boundaries. Each governance layer may be represented in a geospatial database by a geospatial file. Each jurisdiction is governed by distinct rules, actors, and cultural, social, and behavioral codes. By overlaying governance layers in a geographic information system (GIS), jurisdictions overlap, affecting multiple levels of decision-making. Governance layers describe the complexity of water governance in the CRB because they demonstrate overlapping organizations and arrangements as well as the norms and behaviors of actors who have different and sometimes opposing claims in the use, management, and development of water resources.

Special districts such as Ag water supply organizations are central to water development in the CRB. Such service and supply organizations can be classified in two types: 1) private owned by shareholders, and 2) public, which are federal, state, or quasi-governmental. Private Service and Supply Organizations are water utilities, mutual water companies, carrier ditch companies, and mutual ditch and irrigation companies. Public Service and supply organizations are municipalities, irrigation districts, conservancy districts, conservation districts, reclamation districts, water control districts, fresh water supply districts, and municipal water districts. “Water supply organizations such as irrigation and conservancy districts are formed primarily to raise revenue (by property taxation and bond sales) and to construct and operate irrigation projects. Some [organizations] contract with the federal government to administer government-financed reclamation projects” (Getches 2009, p. 453).

Data collection has become more prevalent, and an increasing number

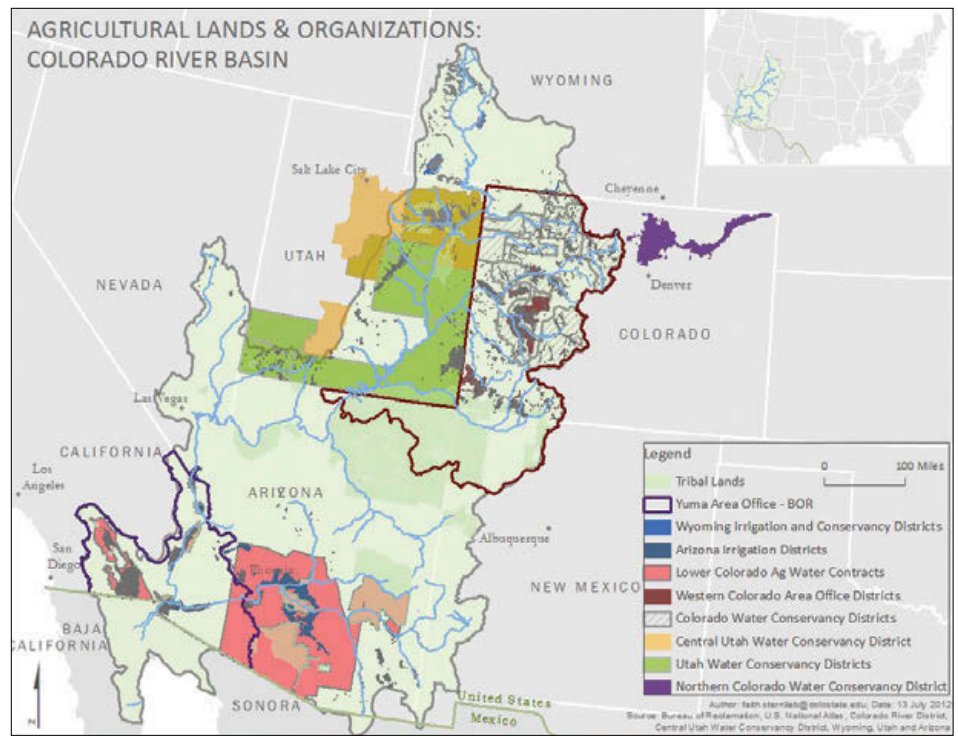


Figure 2. Irrigated and agricultural lands overlaying Ag water supply organizations in the CRB. Ag water supply organizations represented are those that have: a) contracts with the Bureau of Reclamation, b) subcontractors for Colorado River water through Bureau projects (e.g., irrigation districts that have subcontracts for Central Arizona Project water), or c) entities responsible for water supply through state legislature (e.g. Water Conservancy Districts in Utah).

of organizations are collecting data and producing reports, resulting in fragmented datasets. This is especially true in the CRB. Data have been collected continuously from different governmental agencies, CRB states, Ag water supply organizations, and non-profit organizations, as well as local public and private entities. This data collection exercise has been conducted in parallel with The Nature Conservancy-funded project discussed in this issue. Geospatial data includes:

- Hydrologic boundaries defined both by state and by hydrologic unit
- Boundaries for Ag water jurisdictions within the basin including but not limited to Bureau of Reclamation projects (including infrastructure), irrigation districts, water conservancy districts, conservation districts (relating to water management and administration), water users associations, and private irrigation and ditch companies

- Boundaries that demonstrate environmentally sensitive areas such as salinity control areas, wild and scenic stretches of the Colorado River and tributaries, and areas where endangered species are of concern or are actively being protected

Spatial data in the database also includes governance layers describing Mexican jurisdictions. In addition, we are in the process of integrating data on Ag and irrigated lands collected as part a project of The Nature Conservancy in collaboration with CSU (see article on Ag lands in the Colorado River Basin in this issue) and the Geospatial Centroid. Data on Ag water supply organizations together with Ag lands are being compiled to create one comprehensive geospatial database for the CRB (Figure 2).

## Future Research

The Agricultural Water Governance project on CRB and The Nature Conservancy’s project on irrigated

Ag in the CRB combine two datasets that have never before been created. To demonstrate this dataset, an interactive geospatial database is under development. The aim of compiling this dataset is to capture Ag water supply organizations that use Colorado River water and deliver the information through a basin-wide database accessible to water users. The breadth,

depth and purpose of the database are dependent in part on the contributions and sharing of information and data by Ag water users in the CRB and will be useful to them as the water landscape in the CRB changes. Complimentary information about Ag water supply organizations including water rights, contracts, and federal and state policies will be collected and compiled to add

value to the dataset. Representing this information spatially will complement the water quality/availability data that has been collected, processed, and made available. The best available data has been collected. If you are interested in more information about this project or would like to include your data in this database, please contact Faith: [Faith.Sternlieb@colostate.edu](mailto:Faith.Sternlieb@colostate.edu).

## Upper Yampa Scholarships Announced

The Upper Yampa Water Conservancy District John Fetcher Scholarship provides financial assistance to a committed and talented student who is pursuing a water-related career in any major at a public university within the state of Colorado. Congratulations to this year's scholarship recipients, Tyra Monger and Benjamin Von Thaden.

### Tyra Monger

- University: Colorado Mesa University
- Anticipated Graduation: 2014
- Major: Environmental Science and Technology
- Areas of Interest: Watershed

“Being raised on a cattle and hay ranch outside of Hayden, I understand the value of water. I also have understood and been schooled in the value of being a great steward of the land/water. Once I have graduated from Colorado



Mesa University, I am hoping to find a career working in Colorado. Being an outdoors person and being able to maintain the environment have been my lifelong dreams. Currently I am an Environmental Science/Technology major with a Watershed minor. I believe that these programs will become an ever more important field of study to our country and economy. One of the hopes for my future is to return to Routt County to volunteer to further nourish 4-H programs. 4-H provides skills to young adults that can be used throughout their lives as they fulfill their careers. I hope to also be able to help on my family ranch.”

### Benjamin Von Thaden

- University: Colorado State University
- Anticipated Graduation: 2013
- Major: Watershed Science
- Areas of Interest: Water quality monitoring, snow hydrology, water allocation, climate change, and water-related recreation

“I feel very privileged to have been raised in Routt County and I can definitely see myself living and working in the Yampa River Basin in the future. In 2009 I participated in a Tamarisk removal trip on the Yampa River through Dinosaur National Monument. The trip was very eye opening for me and I would like to do more work, and possibly research, in the fight against invasive species such as Tamarisk and Russian Olive in the Colorado River Basin. After I graduate I plan on joining Engineers Without Borders and traveling around South America to help create better access to safe drinking water and improve sanitation. When I was a sophomore at the Lowell Whiteman School I traveled with the school to Bolivia for my foreign trip. As a service project my group installed a water filter, utilizing rocks, gravel, sand, clay, and silt, to provide safe drinking water to a small village close to Rurrenbaque, Bolivia, in the Amazon



Basin. It was an amazing experience to help these less-fortunate people by providing safe drinking water, and I feel I have an obligation to participate in similar projects in the future, hopefully on a larger scale. I have learned that water-related problems are often times very complex and do not have a simple solution, but require collaboration between many groups and industries. While I am not sure of the exact direction that my career will take, I am very excited about having a career in the water industry.”

# Addressing Water for Agriculture in the Colorado River Basin: A Project Progress Report

*Peter Leigh Taylor, Department of Sociology, Colorado State University*  
*MaryLou Smith, Policy and Collaboration Specialist, Colorado Water Institute*  
*Julie Kallenberger, Assistant Regional Water Coordinator, Colorado Water Institute*  
*Faith Sternlieb, Research Associate, Colorado Water Institute*  
*Reagan Waskom, Director, Colorado Water Institute*

Colorado State University's Colorado Water Institute (CWI) is spearheading a U.S. Department of Agriculture-funded research project on water for agriculture in the Colorado River Basin (CRB). Carried out in partnership with the seven CRB land-grant universities—Colorado State University, University of Arizona, University of California, University of Nevada, New Mexico State University, Utah State University, and University of Wyoming (Figure 1)—we want to find out what farmers, ranchers, and water managers are thinking about the current and future status of their agricultural water. Through this project, we hope to identify ways in which land-grant universities can

better assist agricultural water users and managers with the challenges they are facing.

Here, we briefly report on our progress with the research, which includes in-depth exploratory interviews and survey and mapping activities.

## The Interviews

We have completed in-depth telephone interviews with more than sixty farmers, ranchers, and water managers in all seven CRB states. Our other university partners helped us identify areas of high significance for agricultural water within each state and assisted us in contacting potential interviewees. We asked interviewees open ended questions about what

they felt were the main pressures, if any, on agricultural water, how farmers were responding, how they saw the future of agricultural water, and how land-grant universities might help. Although we are in the process of analyzing the rich information from these discussions, below we provide some preliminary thoughts on what we have learned.

## The Survey

The project team will be administering an online survey of farmers and ranchers in selected counties of Colorado and Arizona who use Colorado River water. The survey will address similar topics as those covered in the interviews, but will gather information from a



*The CRB Land-Grant Universities Team at a February 2012 Workshop in Tucson.*  
Photo by Sam Fernald

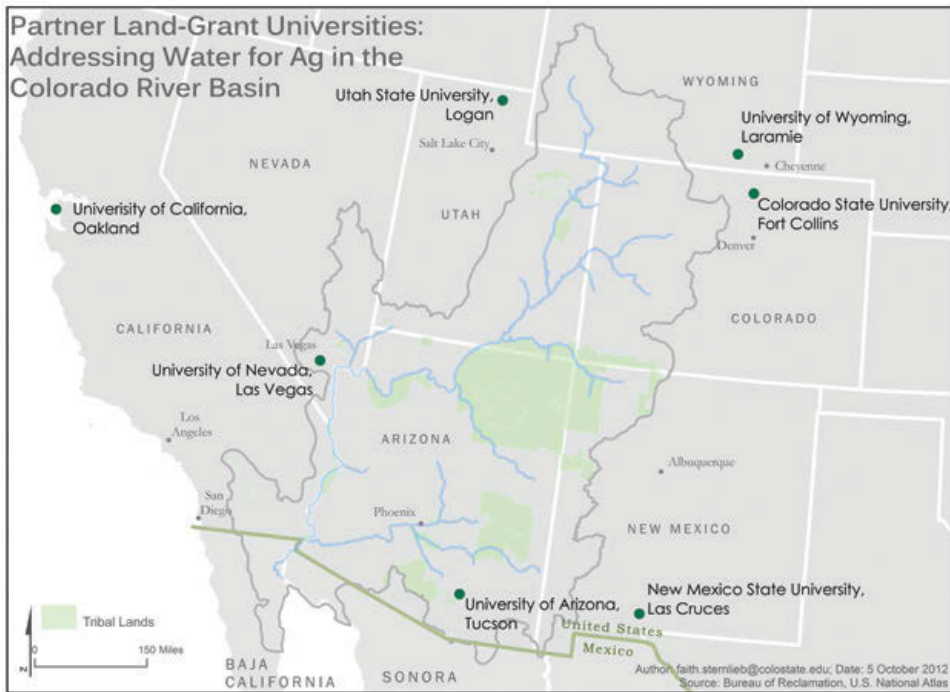


Figure 1. Addressing Water for Ag project team members' Land Grant Universities

broader audience in order to help formulate collective solutions to keep irrigated agriculture viable in the Colorado River Basin. The survey seeks to:

(a) Identify what CRB agricultural water users think about the current and future state of their water supplies and production activities

(b) Identify and compare the attitudes, beliefs, and perceptions held by agricultural water users towards the changes and pressures they are/are not facing with their water supplies, changes in water law and policy, and how to meet future water demands

(c) Gather data on agricultural producers' interest and involvement in temporary and permanent agriculture water transfers and water banks

(d) Identify how agricultural producers work cooperatively with other agricultural and non-agricultural stakeholders

(e) Identify how land-grant universities can better assist farmers and ranchers with the challenges

they are facing, or will be facing with regard to their agricultural water

(f) Gather ideas for projects, partnerships, and other initiatives to work with agricultural producers to help address the challenges they are facing with regard to their water and operations

## The GIS Mapping Activities

The project team conducted a mapping exercise in December 2011 with approximately 40 agricultural representatives from the CRB. A geospatial database is being created to help us better understand how agricultural water is administrated and managed in the seven CRB states. Data collected includes:

- Political jurisdictions including counties, states, tribal lands, counties, and municipalities
- Hydrologic boundaries defined both by state and by hydrologic unit
- Agricultural water jurisdictions within the basin including Bureau of Reclamation projects, irrigation districts, water conservancy districts and conservation

districts, water users associations, and private irrigation and ditch companies

- Environmentally sensitive areas such as salinity control areas, designated wild and scenic stretches of the Colorado River and tributaries, and areas where endangered species are identified as of concern or are actively being protected

Maps have also been an integral part of the interview process. With help from water leaders in each state, we created maps to help us locate areas where agricultural water is especially important and where we needed to interview individuals and key water organizations' representatives (see Figure 2 for interviewee locations). Though the interviewees' identities are confidential, during the interviews we referenced digital maps showing local political jurisdictions, waterways and other features to help us locate our discussion in the complex geographic space occupied by the interviewees.

All of the base maps were created from a comprehensive geospatial database of the CRB that is being developed under the direction of Melinda Laituri (see both articles on agricultural water governance and agricultural lands in this issue).

## Preliminary Results from the Interviews

Agricultural water users across the CRB are of course, very diverse. They operate across geographical contexts that vary from Upper to Lower Basin, high-altitude to sea level areas, and from forested to semiarid regions. They engage in a wide range of agricultural activities, from cattle ranching and cropping of pasture, alfalfa, and small grains, to high value vegetables, fruits, nuts, and more. Agricultural water users



Figure 2. Pushpins indicate where interviews were conducted with agricultural water managers, users, and their respective agricultural water supply organizations.

and managers operate under the 1922 Colorado River Compact and the Law of the River, yet each state provides distinctive frameworks for agricultural water use, management, and transfer. Agricultural water users and managers operate in a complex set of organizational contexts, from individual surface water diverters and groundwater users to ditch companies, irrigation districts, and water conservancy districts. Nevertheless, agricultural water users and managers report a number of common challenges (though their experience of them is shaped by geographic location, the history and seniority of their water rights, the type of agriculture and ranching, the proximity of urban areas and other competing water users, etc.).

These common challenges include uncertain water supplies, extended drought and the threat of climate change, and competition and conflicts with other water users within

agriculture and from energy, environmental, recreational, and municipal/ industrial sectors. Many respondents have talked about the need for storage to manage effectively for multiple use and conservation but often express concern about the barriers posed by negative public views of storage and time-consuming and expensive permitting processes. Conjunctive management of surface and

groundwater poses increasingly complex problems of water access and management. Many have commented on how government regulatory frameworks, especially the Endangered Species Act, the National Environmental Protection Act, the Clean Water Act, and health and safety regulations, have fundamentally changed not only how water is used, but agricultural production itself. Many farmers have expressed concern about the need to strengthen public understanding of the importance of agriculture for a secure and healthy food supply. Many also have observed that the key role irrigated agriculture plays in creating ecological and amenity values is not well understood by many in the environmental and recreation communities. Others have remarked on the increasingly litigious environments in which discussions of water are occurring and suggested that more real progress can be made when people can stay out of court. Our interviewees have also

spoken, often with great poignancy, about uncertain futures for family farms and agribusinesses as younger generations choose not to continue in agriculture. Numerous interviewees have spoken of farming's future as one integrated with growing cities, with fewer traditional operations and many smaller "amenity" farms. Some farmers spoke of selling parts of their land and water rights to developers or even acting themselves as development investors, with returns reinvested in agriculture elsewhere or in helping secure their retirement.

It seems clear that agricultural water users are not affected the same way by the challenges facing them today. Many interviewees describe themselves as positioned to move ahead and either surmount these challenges or adapt to them in new and productive ways. These well-positioned users of agricultural water are found in all parts of the CRB represented by our interviews. Yet agriculture and agricultural water is described as strongest where geographic and climatic conditions allow highly productive agriculture with year-round, high-value commercial cropping. Water users with the most senior water rights are more cushioned from the uncertainties of an intensively used river and of supplies threatened by extended drought and predicted climate change. Though having urban areas nearby generally results in significant pressures from non-agricultural water demands, transportation and communication infrastructure also mean lower costs of production and marketing. Significantly, it is in these areas that interviewees spoke more consistently of new generations entering farming, ranching and related agribusiness.

Agricultural water users working in geographical areas where climatic and soil conditions pose higher obstacles to productivity, shorter growing



seasons, and greater isolation from markets face special challenges in adapting to new water pressures. More of these respondents spoke poignantly about their sense of the threats to a traditional farming way of life, as their children seek futures outside of agriculture. Yet these interviewees are clearly not giving up; on the contrary, they express deep commitments to what is in many cases, multi-generational investments in their land, water and agricultural way of life. They also express a strong commitment to providing food for our society, and their concern for national food security. Moreover, they are working hard to develop innovative ways to protect their water and their communities.

Indeed, interviewees throughout the CRB have talked about innovative strategies they are developing to overcome or adapt to pressures on agricultural water. In many areas, as in California, Arizona, and Colorado, agricultural water users and managers have embarked on new agreements with large urban water users to develop water supplies for multiple objectives, including urban, environmental, recreation, and agriculture. Several water managers have described their organizations' services to multiple user groups and their need to plan for more urban and municipal demands while maintaining support for agriculture. In several areas, such as Wyoming, Colorado, and New Mexico, multi-stakeholder forums and organizations have formed to try to manage conflicting claims and perspectives on water by bringing agriculture, environmental, recreation, and other groups to the negotiating table. These initiatives are not easy and have had mixed results, but

participants in successful experiences have spoken of what can be achieved with key visionary leaders, a focus on common interests of all parties in healthy local economies and riparian ecologies, willingness of all user groups to compromise, and a commitment to generating concrete results quickly, even if on a small scale. Other innovative responses reported by interviewees include diverse groundwater recharge programs, formal and informal water banking, and a range of leasing mechanisms. Numerous interviewees have reported on innovative approaches to planning storage as a key to developing secure future supplies of water for multiple uses, including agriculture, environmental, and recreational uses.

### What Needs to be Done?

Our interviewees have spoken of possible paths to a positive future for agricultural water. They suggest that the broader public might be helped to better understand the importance of irrigated agriculture, not just for securing high quality and safe food for our nation, but also for creating significant environmental and amenity values. As one Wyoming rancher put it, "This is an oasis in the

high desert. But God didn't make the oasis. It's man-made. It takes lots of water, diverted regularly in almost impossible quantities to keep it that way." Interviewees remarked that regulatory frameworks could better recognize both the continuing need for a viable agriculture throughout the CRB as well as its obstacles. Competing water users/stakeholders could develop more effective ways to negotiate based on understanding if not agreement with other perspectives and the need for a strong agriculture in the future.

### What is the Role of Land-grant Universities?

Most interviewees have expressed positive views of land-grant universities. They speak of the Extension agents who help them improve efficiency of irrigation technology and water management, introduce new seeds, and implement better soil practices. Interestingly, although most of our open-ended questions about the agricultural water community's challenges stimulated discussion of issues that are largely political, economic, social, and cultural in nature, relatively few respondents had experience with universities helping with these issues. This suggests to us that land-grant universities have an opportunity to bring to bear new kinds of social science research and outreach on the problems facing agricultural water users and managers, in addition to their traditional strengths in natural science and more technical disciplines.

Results from the Addressing Water for Agriculture in the Colorado River Basin project will be summarized and posted on the project website ([www.CRBwater.colostate.edu](http://www.CRBwater.colostate.edu)) in the spring of 2013.



*The Water for Agriculture Interview Team at CSU.*

Photo by Bridget Julian

# Integrating Environmental and Recreational Water Needs with Traditional Demands on Colorado Basin Water Resources

*Hannah Holm, Coordinator, Water Center at Colorado Mesa University*

The Colorado River, in its entirety, provides water to over 27 million people and 3.5 million irrigated acres in seven states and two countries. It has frequently been labeled one of the most litigated rivers in the world. Within Colorado, efforts to appropriate water from the river for thirsty farms and cities on the eastern plains, on the one hand, and to reserve its water for future Western Slope growth on the other, helped spawn some of the state's major water bureaucracies: the Northern Colorado Water Conservancy District, the Colorado River Water Conservation District, and the Colorado Water Conservation Board. These institutions all celebrated their 75th anniversaries in 2012.

Historically, tussles over the river have focused on who has the right to consume water from the river, and pressures to consume more continue unabated, with projections of a near doubling of the state's population by 2050. Since the 1970s, however, these standard tussles have been complicated by growing demands to keep enough water in streams, at the right times, to support healthy ecosystems and protect recreational opportunities for boaters and anglers. Over time, responding to these demands has become increasingly integrated into negotiations over the river's future.

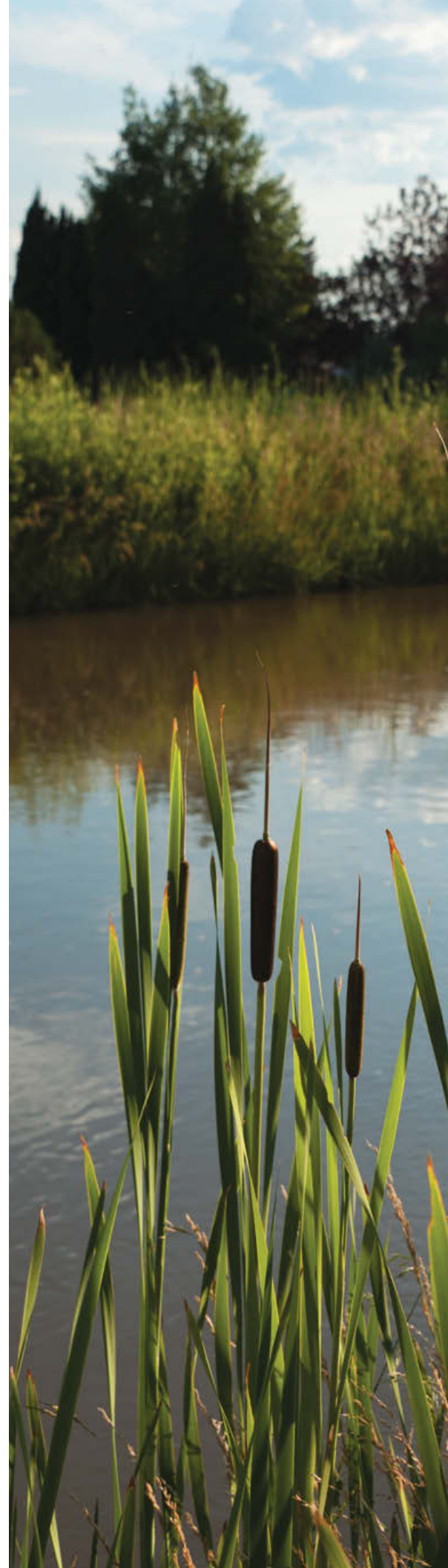
Pressures to accommodate environmental and recreational flow needs have come from two directions: the need to comply with the federal Endangered Species Act, and the change in public values that caused the act to be adopted. The

tools for accommodating these "new" needs include spending money on technical solutions and highlighting the economic value of healthy streams that provide recreational assets. Even as these tools are used to push for more water for the environment and recreation, studies continue to be undertaken to better understand what flows these uses really need.

This article briefly reviews three efforts to obtain water for environmental and recreational needs within the Colorado River basin: the work of the Upper Colorado River Endangered Fish Recovery Program to increase flows in a reach of critical habitat, the Colorado Cooperative Agreement between Denver and numerous Western Slope entities, and current state and basin-wide water planning and study processes. These cases demonstrate how efforts to achieve flows to benefit environmental and recreational needs have become intertwined with historic negotiations on the allocation of the river for consumptive uses. They also point to new ways of understanding what rivers really need, and what communities need from their rivers.

## **Endangered Fish Recovery Program in the "15-Mile Reach"**

The desire to avoid having all water development activities in the Colorado and its tributaries





The Highline Canal, where a project involving technological upgrades maintains water flow in the canal.

Photo by Bill Cotton

held up by consultations required under the Endangered Species Act to avoid harm to four species of endangered fish in the lower reaches of the river in the state (Colorado Pikeminnow, Razorback Sucker, Humpback Chub, and Bonytail) provided a powerful incentive for all parties with a stake in water development to cooperate on a common plan to help the species recover.<sup>1</sup> One aspect of the plan has been for each of the major diverters upstream of the critical habitat in the “15 mile reach” that flows through Grand Junction between a major irrigation diversion and the confluence with the Gunnison River to donate water to meet the flow needs of the fish—a strategy made possible only by the existence of upstream reservoirs.<sup>2</sup>

Another aspect has involved technological upgrades to the Government Highline Canal, which takes water from the roller dam at the top of the reach and is managed by the Grand Valley Water Users Association. Upgrades to this canal include installing a series of checks that enable delivery throughout the canal system without diverting as much “carry water,” which formerly spilled back into the river at the

end of the system. This has enabled additional water to stay in the 15-mile reach without reducing the amount available for irrigation.<sup>3</sup> A similar project is currently under way with the Orchard Mesa Irrigation District.

Enhancing flows in this section of critical habitat has required an excruciating degree of negotiation and cooperation by many parties. It was also enhanced by the existence of resources to facilitate “win-win” solutions, once they were identified: water resources from reservoirs, and significant financial resources.

## Colorado Cooperative Agreement

An almost-final agreement between Denver Water and numerous Western Slope local governments and water providers is in some senses a truce in the continual cross-divide tug-of-war over the river. The detailed agreement includes Western Slope entities agreeing not to protest an increase in Denver Water’s trans-mountain diversions through the Moffat Collection System Project and Denver Water agreeing not to try to develop any more Colorado River water without the consent of the “donor” county.<sup>4</sup>

However, the agreement also acknowledges the ecological damage

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<sup>1</sup> George Sibley describes these dynamics in his book *Water Wranglers: the 75-Year History of the Colorado River District: A Story About the Embattled Colorado River and the Growth of the West*, in Chapter 33: “Fish Endangered by Development Endanger Further Development.”

<sup>2</sup> Technical documents related to this agreement, including the “Water Users Commitment Letter” to split the obligation to provide a 10,825 acre-foot “fish pool” between East Slope and West Slope water users, can be found at [www.coloradoriverrecovery.org](http://www.coloradoriverrecovery.org), the website for the Upper Colorado River Endangered Fish Recovery Program.

<sup>3</sup> For details on this project, see ITRC Report # 03-009: *Government Highline Canal – A Win-Win Solution* from the Irrigation Training and Research Center at California Polytechnic University, which is available at <http://www.itrc.org/reports/highline/highline.pdf>.

<sup>4</sup> The full agreement, summaries and press coverage can be found at [www.denverwater.org/SupplyPlanning/Planning/ColoradoRiverCooperativeAgreement/](http://www.denverwater.org/SupplyPlanning/Planning/ColoradoRiverCooperativeAgreement/).

done by decades of trans-mountain diversions. Reflecting both the value headwaters communities place on healthy streams and the need to continually refine knowledge on what streams need, the agreement includes a provision for “learning by doing” to manage flows for the benefit of the environment in the Upper Colorado Basin. A similar agreement is under negotiation between the Colorado River District and the Northern Water Conservancy District.

## State and Basin-Wide Water Study and Planning Initiatives

Major statewide and basin-wide planning and study processes are currently underway that seek to balance supply and demand, which are beginning to look seriously out of balance. Within Colorado, the Colorado Water Conservation Board has spearheaded two iterations of the Statewide Water Supply Initiative (SWSI), the latest completed in December 2010,<sup>5</sup> and the Bureau of Reclamation is currently coordinating a comprehensive Colorado River Basin Water Supply and Demand Study, which is due to be released in its entirety in November 2012.<sup>6</sup>

With SWSI 2010 as a departure point, the CWCB is supporting basin roundtables of stakeholders in each of the state’s major river basins and the Denver metro area in developing a statewide water plan by 2016. The basin roundtables have been charged with conducting assessments of their basins’ water

needs for both “consumptive” uses (drinking, irrigation and industrial uses) and “non-consumptive” uses (environmental and recreational uses), as well as providing input on how best to meet a shortfall between anticipated needs for growing cities and supplies expected from already planned projects.<sup>7</sup>

While all the basin roundtables in the state assessed important environmental and recreational attributes in their basins, the Colorado Basin Roundtable went a step further toward attempting to quantify the water requirements for watershed health by commissioning a watershed flow evaluation tool. The tool provides a broad-brush picture of where stream-based ecological resources may have changed as a result of flow alternations, as well as how current flows compare to flows considered suitable for whitewater boating in reaches where that has been identified as an important attribute.<sup>8</sup>

At the same time as these environmental studies on ecological flow needs have been underway, two studies on the economic value of river flows have also received significant media attention and have worked their way into the debate over different options for balancing water supply and demand in the state and in the basin. The Northwest Colorado Council of Governments commissioned a study entitled *Water and its Relationship to the Economies of the Headwaters Counties*,<sup>9</sup> which attempts to demonstrate that stream depletions

in headwaters counties have economic consequences as well as ecological consequences.

In addition, a study commissioned by Protect the Flows, a coalition of businesses that rely on the Colorado River, claimed that flowing water in the Colorado River stimulates \$26 billion in economic activity every year and employs 234,000 people.<sup>10</sup> The organization uses the study to support its calls for enhanced conservation rather than additional diversions to balance supply and demand, and explicitly acknowledges that it is seeking to influence the outcome of the Bureau of Reclamation’s basin-wide study.

## Conclusion

How to reconcile environmental and recreational needs for water with growing consumptive needs is far from resolved. However, these examples show that attempts to do so have become part of the mainstream of negotiations over water allocation, at least within Colorado’s portion of the Colorado River Basin—and that with the right alignment of motivation and resources, win-win solutions are possible. They also show evolution in the tools used to understand environmental and recreational water needs, and the public debate on those needs. Despite the potential for even greater competition over Colorado River water resources in the future, it is unlikely that this debate will subside.

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<sup>5</sup> The full report and supporting documents can be found on the Colorado Water Conservation Board’s Water Supply page: <http://cwcb.state.co.us/water-management/water-supply-planning/Pages/main.aspx>.

<sup>6</sup> Study information, including interim reports, are available from the Bureau of Reclamation at <http://www.usbr.gov/lc/region/programs/crbstudy.html>.

<sup>7</sup> More information on basin roundtables can be found at <http://cwcb.state.co.us/water-management/basin-roundtables>.

<sup>8</sup> The study team’s website contains multiple documents on the process of developing the tool: <http://www.cobasinwfet.org/home>.

<sup>9</sup> Available here: [http://nwccog.org/docs/qg/QQStudy\\_Report\\_Jan%202012.pdf](http://nwccog.org/docs/qg/QQStudy_Report_Jan%202012.pdf).

<sup>10</sup> Report available at <http://protectflows.com/>.



Author George Sibley, center, is interviewed by Eric Kuhn, left, and Jim Pokrandt at the Colorado River District's Annual Water Seminar on September 13, 2012. Courtesy of the Colorado River District

## Colorado River District Celebrates 75<sup>th</sup> Anniversary

*Jim Pokrandt, Communications and Education, Colorado River District*

The Colorado River District's (CRD) 75<sup>th</sup> anniversary in 2012 has been cause to celebrate the organization's founding, but more importantly, the reasons why: the necessity to protect Western Colorado water and balance demands on the Colorado River in an arid state where most of the people live on the east side of the Continental Divide and most of the surface water is on the west side.

This celebratory thread has been woven throughout the CRD's many public events and invitations to speak to community groups, culminating in the District's Annual Water Seminar held September 13 in Grand Junction, attended by 190 people.

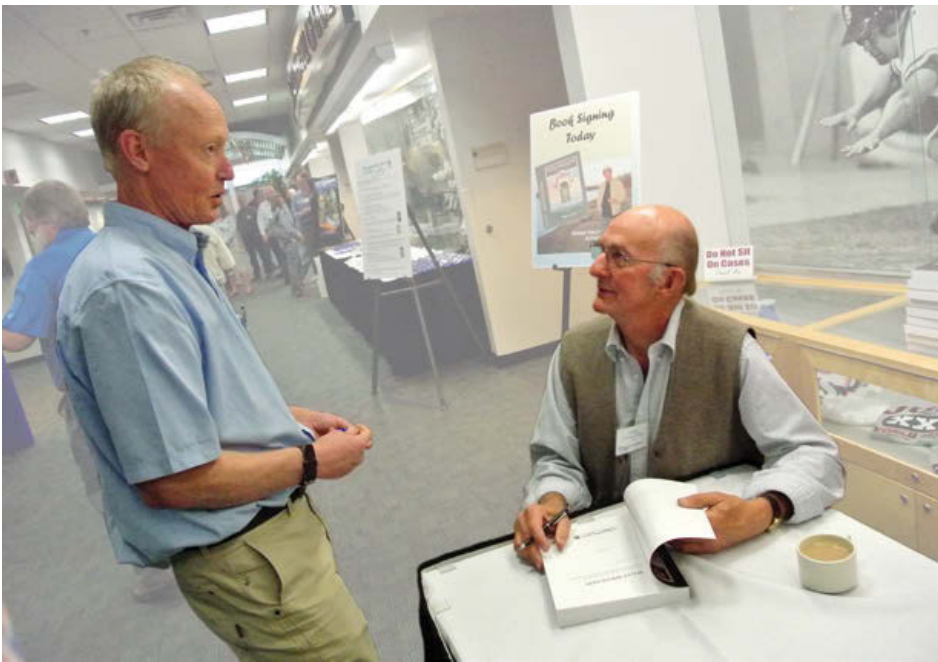
The seminar agenda was a perfect reflection of the anniversary and the foundational issues of western water. Most of all, the seminar was the occasion to introduce the book *Water Wranglers, The 75-Year History of the Colorado River District: A*

*Story About the Embattled Colorado River and the Growth of the West.* The 466-page, soft-cover book was commissioned by the Colorado River District to tell the story of not only the organization but the trials and tribulations surrounding the Colorado River. Author George Sibley was on hand at the seminar to autograph books. As part of the program, Sibley was interviewed on stage by CRD General Manager Eric Kuhn and Communications Specialist Jim Pokrandt.

As the book points out, the story of the CRD is the story of water development in Colorado and the West. The 2012 Seminar focused on two other subjects that were as much a concern in 1937 as they are in 2012: how to deal with demand for water that promises to exceed supply and the overlay of drought, in this case, the drought of 2012. The modern-day take on Colorado River shortages is incorporated in the Colorado River Basin Water Supply and Demand

Study undertaken by the Bureau of Reclamation and the seven states that are signatories to the Colorado River Compact of 1922. The study predicts demand exceeding supply in the coming decades by as much as two million acre feet under a climate change scenario. The study is due to be final by the end of November 2012.

The study was detailed by Co-Managers Carly Jerla and Kay Brothers. As Brothers pointed out, water managers must plan for the worse and the hope is that the study advances planning for how the states, water managers, and other interests cope with the imbalances. A panel discussion ensued with Eric Hecox of the South Metro Water Supply Authority representing an important water-seeking region in Colorado, Jennifer Pitt of the Environmental Defense Fund addressing environmental concerns, Chuck Cullom of the Central Arizona Project bringing a Lower Basin perspective, and Eric



*Richard Van Gytenbeek of Trout Unlimited awaits a signed copy of George Sibley's book "Water Wranglers, the 75-Year History of the Colorado River District: A Story About the Embattled Colorado River and the Growth of the West." The book debuted at the Colorado River District's Annual Water Seminar on September 13, 2012.*  
 Courtesy of the Colorado River District

Kuhn of the Colorado River District tying in Western Colorado concerns.

The seminar also reviewed the headlines most current: the 2012 drought. State Climatologist Nolan Doesken of Colorado State University said 2012 was the fourth worst drought on record, exceeded only by the years 1934, 1977 and 2002. A panel reviewed how the drought has affected West Slope municipal providers, agriculture, and canal operators and how the Colorado Water Conservation Board responded to local conditions. Speaking were Carlyle Currier, a rancher on the Grand Mesa; Dick Proctor, Manager of the Grand Valley Water Users Association; Greg Trainor, Utility Director for Grand Junction; and Taryn Hutchins-Cabibi, who guides Drought Planning and Climate Change for the Colorado Water Conservation Board.

The keynote speaker for the seminar was Anne Castle, the well-known Colorado attorney and water law expert who is now the U.S. Assistant Secretary of the Interior for Water and

Science. She praised the CRD's work over the years, noting the collaboration and innovation that was often born out of the eternal conflicts over the Colorado River.

The CRD was founded as a direct response to the creation of the Colorado-Big Thompson transmountain diversion project, the first big one

in the state to move Colorado River water from west to east. The legislature established the CRD as the entity to protect Western Colorado water in the many debates over transmountain water and to safeguard all of Colorado's interest in the Colorado River in multi-state negotiations. Furthermore, the CRD was created to develop water for use on the West Slope. It became a partner with the Bureau of Reclamation to create West Slope projects such as the Silt Project, the Paonia Project, and the Aspinall Unit. It went on to develop or enlarge water storage at Rangely, Wolford Mountain, and Elkhead.

In a sense, not much has changed in 75 years. The topics today are the same as 1937: balancing demand, protecting the West Slope, compensatory storage, maintaining streamflows, and championing the reasons many have come to the West Slope whether it be recreation, the environment, agriculture, or other economic drivers dependent on adequate water supply.

Videos of the seminar and information on how to obtain the book *Water Wranglers* can be obtained at [www.ColoradoRiverDistrict.org](http://www.ColoradoRiverDistrict.org).



*At the Colorado River District's Annual Water Seminar on September 13, 2012, speakers addressed the Colorado River Basin Water Supply and Demand Study. Among them, from left, were Jennifer Pitt of the Environmental Defense Fund and Study Co-Managers Kay Brothers and Carly Jerla.*

Courtesy of the Colorado River District

# Northern Water Turns 75

Brian Werner, Communications and Records Department Manager, Northern Water

About 250 people celebrated Northern Water's 75<sup>th</sup> anniversary on September 20 at their Berthoud headquarters. A public ceremony to commemorate the occasion included brief remarks by Northern Water Board President Mike Applegate, Reclamation Regional Director Mike Ryan, former Senator Hank Brown, and Colorado State University professor emeritus Dan Tyler. An open house and tours of the facilities and award-winning Conservation Gardens followed.

The September 20 festivities marked the diamond anniversary of the state's oldest water conservancy district.

Colorado's legislature passed the Water Conservancy District Act in May 1937, creating the framework for the establishment of water conservancy districts. Four months later on September 20, 1937, the Northern Colorado Water Conservancy District was established by the Weld County District Court.

Northern Water, as it is now known, was created to be the local sponsoring agency to contract with the U.S. Bureau of Reclamation to build, operate, maintain, and administer the Colorado-Big Thompson Project (C-BT), Colorado's largest transmountain diversion. The C-BT transports nearly 220,000 acre feet of water annually from the headwaters of the Colorado River to northeastern Colorado to supplement the region's erratic natural supply. This water is used to meet municipal, industrial, agricultural and recreational needs.

The September 20 event capped a yearlong effort to celebrate the contributions Northern Water and the C-BT Project have made to the region and to recognize those who had the vision that brought the project to fruition.



General Manager Eric Wilkinson addressing the crowd on September 20.  
Courtesy of Northern Water

In addition to the afternoon celebration and open house, Northern Water produced a 75th anniversary edition of its flagship publication, *Waternews*, which is available for download at [northernwater.org](http://northernwater.org) or by requesting a printed copy at 800-369-7246. An exhibit featuring black and white historical photos is on display at the Berthoud headquarters building.

The program culminated Northern Water's anniversary year effort to recognize all those who have contributed to the C-BT's success, and many of the presenters spoke of the original board members and organizers who stuck their necks out to get a project built. The C-BT has generated more than \$500 million in energy production, more than \$300 million in annual agricultural production, and a water supply that today is worth more than \$3 billion. Those benefits are for a project that cost the water users of northeastern Colorado \$25 million out of a total project cost of \$164 million.

General Manager Eric Wilkinson emceed the ceremony and gave kudos to the visionaries who dared to dream about the C-BT. He asked the

crowd to imagine what it would have been like to walk out of that Greeley courthouse 75 years ago with a piece of paper that gave the official stamp of approval to an organization that faced the daunting task of getting the C-BT Project built.

Wilkinson described the scenario these leaders had just created for themselves—to build the largest transmountain diversion project in the state and one of the largest Reclamation projects in the American West, to convince citizens that it made sense, and then work out all the necessary financial details. They did so, and when the original board asked voters if they were willing to assume part of the repayment obligation through an ad valorem property tax, they overwhelmingly approved it with 94 percent voting yes.

Ryan talked about the relationship between the federal Bureau of Reclamation and Northern Water during the C-BT's 20-year construction period. He spoke of the engineering accomplishment that allowed a 13-mile-long tunnel to be constructed underneath Rocky Mountain National Park from two separate ends. When crews met in the middle and holed through they were less than a penny's width off in alignment, an incredible feat for that day.

Brown talked about the early settlers who transformed a region explorers had called the Great American Desert into something quite different, primarily thanks to water projects like the C-BT. He credited visionaries, including Charles Hansen and WD Farr, with their foresight and contributions that helped make the region we enjoy today.

Applegate spoke about legacies and his hope that future generations will



Attendees enjoy touring the Conservation Gardens prior to the ceremony.

Courtesy of Northern Water

look back on today's water managers with the same respect we have for the C-BT visionaries of 75 years ago. He charged today's water leaders with

the honorable and challenging task of providing the same foresight in preparing for the next 75 years.

Tyler, whose *Last Water Hole in the West* is the definitive history of Northern Water and the C-BT Project, offered his thoughts on the board, staff, and legal counsel who helped shape Northern Water. He said the staff and board of today should be proud of where Northern Water has come. He stated the stability of both board and staff have provided the citizens of Northeastern Colorado with leadership and vision that is hard to match.

Northern Water's anniversary coincided with both the Colorado Water Conservation Board and Colorado River District, both of which were created in 1937 by the Colorado legislature. Together these three organizations helped lay the foundation for water management in the state, a role they still share in today.

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Colorado State University

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# Preparing for Fire, Protecting Water

## Southern Colorado Community's Fire Mitigation Efforts to Benefit Watersheds

*Ryan Lockwood, Public and Media Relations Coordinator, Colorado State Forest Service*

**W**ith 325 acres completed this year to complement existing fuelbreaks in the community, a mountain subdivision along the New Mexico border has now treated more than 3,000 forested acres, becoming a model for how Colorado communities can band together to reduce wildfire risk. And when a large fire does threaten, fire mitigation work also will ultimately benefit local watersheds.

Santa Fe Trail Ranch covers approximately 17,000 acres across two important watersheds in the foothills southwest of Trinidad. I-25 provides primary access to the ranch, which abuts the state line on the south. Treatments to reduce wildfire risk in the community have been ongoing since 2005, when community leaders

utilized funding and assistance from the Colorado State Forest Service (CSFS) to stimulate widespread landowner involvement. Nearly 15 miles of fuelbreaks along roads, trails, ridgelines, and other focal areas within or adjacent to the subdivision are now established to slow the spread and diminish the intensity of an approaching wildfire.

“Now we stand a chance when the big one hits,” said Dave Skogberg, a community leader who has been a catalyst to collective efforts.

### **A Community at Risk**

Santa Fe Trail Ranch consists of 454 lots on steep terrain, each about 35 acres. Historic fires created a forest mosaic of ponderosa and piñon pine,

juniper and Douglas-fir. Beneath the forest canopy, a thick shrub understory composed of Gambel oak, New Mexico locust, mountain mahogany, skunk-bush, and choke-cherry dominates the landscape. Fire history studies show that natural, low-intensity fires once burned in this type of ecosystem every 13 years or less. But the vegetation grows dangerously dense in the absence of regular fires, which creates the potential for more intense wildfire events. And in the long run, wildfire in this area is inevitable.

“Having a fire here is not a matter of if, but a matter of when,” said R.C. Ghormley, another resident who has been pivotal to community-wide fire mitigation.



*A heavy helicopter drops water on the Track Fire.  
Courtesy of CSFS*



*Untreated areas on the ranch (left) exhibit much higher tree densities than completed fuelbreaks (right).*

Courtesy of CSFS

An intense wildfire in the area could result in excessive runoff and sedimentation to Raton Creek and Trinidad Lake. Also, ponds in the area could fill with sediment, compromising the water supply for wildlife and livestock.

Besides lightning-strike fires that occur almost annually on the ranch, large wildfires are common in the surrounding area. The Morley Fire burned 300 acres within the subdivision in 1978. In 2002, three large fires together burned 40,000 acres near the subdivision. Then, in 2011, the 27,000-acre Track Fire was within three miles and headed for the ranch before a wind shift diverted it away and across I-25. Mark Loveall, assistant district forester with the CSFS La Veta District, says these events all highlight the need to be prepared before a fire arrives.

“To prevent loss of structures during a wildfire, each landowner needs to take the steps necessary to protect his or her property,” said Loveall.

### Recent Fuelbreaks Focus on Escape Routes, Fire Spread

Two fuelbreaks, each several miles long and 300 feet or more wide, were completed this summer. Much of the 325 acres treated were located along

the Gallinas Parkway Conservancy—land owned by the Colorado-based Greenlands Reserve Landtrust. The parkway leads to the subdivision entrance off I-25, which is the only major exit route for residents in an emergency. The other major fuelbreak was created along a four-wheel-drive trail within the community’s southern borders to help prevent fire spread within the community. Volunteer crews from the subdivision used chainsaws to complete smaller fuel reduction areas complementing the major fuelbreaks, and carted off larger logs to become firewood.

“We’re making lines of resistance, to prevent fire from spreading through the community,” said Ghormley.

Ghormley took the lead in applying for \$240,000 in Emergency Supplemental Funds, which are administered by CSFS, to cover the cost of the fuelbreaks and some mitigation work on private lots. In addition to the \$240,000 they received, landowners personally covered other costs to treat hundreds more acres on their own properties, through agreements with Rue Logging, Inc.—the contractor that created the fuelbreaks.

The Santa Fe Trail Ranch fuelbreaks are considered “shaded fuelbreaks,”

which means that tree stands and understory vegetation are only selectively thinned. Many larger, more fire-tolerant trees are left standing in the broad fuelbreaks, along with clumps of oak brush and some smaller trees, which are retained for wildlife habitat and aesthetic purposes. Loveall says the fuelbreaks encourage approaching wildfires to transition from catastrophic crown fires to less-intense ground fires.

Besides posing a greater risk to human life and property, high-intensity fires negatively impact watersheds. They consume nearly all the vegetation that would normally intercept raindrops and slow runoff, and they create water-repellent soils. An intense wildfire at Santa Fe Trail Ranch would result in significant increases in erosion and reduced water quality in Raton Creek and Trinidad Lake.

To moderate the risk of high-intensity fire, loggers used five pieces of heavy machinery to reduce tree densities in fuelbreaks at the ranch from approximately 300 trees per acre to between 30 and 80 trees per acre—a more natural tree density. Machinery ground most of the woody material into mulch. Skogberg says that when the contractor was

brought in, residents requested additional work on individual lots while the machinery was still on site. Approximately 3,000 acres have now been treated within or along the edge of the subdivision, or nearly 20 percent of the land area.

Loveall says the organizational skills of Ghormley and his wife, Mary, were key to the overall success of the recent projects. “They kept constant track of grant funding available through the CSFS, assembled groups of residents to assist foresters with layout and mapping, and allowed their home to be used as a planning and meeting headquarters,” he said.

## Community Wildfire Protection Plan Vital to Success

In order to meet CSFS funding requirements, the subdivision needed to have an approved Community Wildfire Protection Plan (CWPP) in place. CWPPs were authorized and defined by the 2003 Healthy Forests Restoration Act, with the intention of bringing together local communities and government agencies to address wildfire preparedness and fuels reduction in the wildland-urban interface. Approved CWPPs are required to compete for many federal grants to implement forest treatments.

The Santa Fe Trails Ranch CWPP is one of 200 plans now completed in Colorado.

“The progress made over the years at Santa Fe Trail Ranch clearly points to the value of CWPP development as the critical starting step,” Loveall said.

Top priorities laid out in the Santa Fe Trails Ranch CWPP include implementation of a universal street-addressing system (to make navigation easier for responding firefighters), creating defensible space around structures wherever possible, and creating maps for use by firefighters during an incident. Another priority defined in the CWPP was making the Gallinas Parkway—addressed by 2012 fuelbreaks—into a safer emergency route for evacuating landowners and arriving firefighters.

## CSFS Funding Pivotal to Implementation of Past Work

The 2012 fuelbreaks are only the latest in a series of projects Santa Fe Trail Ranch has implemented to protect the community from wildfires. From 2005-2009, the community applied CSFS-administered State Fire Assistance grants and Colorado Forest Restoration Pilot Program funds to help create defensible space around homes and create earlier fuelbreaks. Thousands of hours of

landowner labor were used to help match this grant funding. In 2007, a large fuelbreak was completed along the southwestern boundary of the community, with matching funding coming from the Vermejo Park Ranch, where much of the fuelbreak is located. In 2009, another fuelbreak partially funded by CSFS grants was completed along the southern border of the community near the state line.

The community has held many weekend volunteer parties where members get together to do work and put wood chippers owned by residents to use. Residents also have created the non-profit Forest Health Coalition to extend their mission beyond the community and educate other forested communities in southern Colorado.

“It’s a pretty active group,” said Skogberg. He says that an added benefit to the community is that past fuelbreaks have become the favored habitat of many animals, including elk and turkeys.

Loveall and C.K. Morey, CSFS La Veta District forester, have made frequent trips to the subdivision to guide the property owners through the steps needed to create effective fuelbreaks and obtain grant funding. Loveall says that heavy involvement by residents like Skogberg and the Ghormleys has been pivotal to making the subdivision safer.

“I am confident that the work done in this community will aid firefighters in keeping most fire starts from destroying structures and threatening public safety,” Loveall said.

For more information about Community Wildfire Protection Plans and grant funding for fire mitigation, go to <http://csfs.colostate.edu>.



*A mechanical masticator grinds a juniper tree into mulch.*

Courtesy of R.C. Ghormley



## 30 Years of Salinity Programming—What Does it Mean for the Colorado Today?

*Denis Reich, Water Resources Specialist, CSU Extension, Colorado Water Institute*

For anyone who's driven past the Bookcliffs desert near the Grand Junction airport in the spring, salt is a common sight. The streaks of white are sometimes as thick as heavy frost on the adobe hills. This is Colorado River Basin salt at its most visible. The less obvious behind-the-scenes story is soil borne salt's contamination of our most famous Western river. The response, the Colorado River Salinity Control Program, has been one of the most involved yet successful water quality programs in United States history.

With an average of about 10 inches of precipitation per year, the tight clay soils of Western Colorado's arid agricultural valleys—such the Grand and Uncompahgre—see few downpours or sustained showers. This prolonged lack of water has historically not been enough to penetrate below the surface and flush the resident mineralized

salts—the same that surface in the adobes each spring—out of the clay subsoil and downstream.

With the arrival of Europeans to Western Colorado, irrigated agriculture effectively raised the average application of water from a few inches to a few feet. As canals and headgates were installed, the desert bloomed. Less dramatic were the millions of tons of otherwise dormant salt that irrigation water, percolating deep into the soil, began quietly releasing into rivers. It took a few decades, but once reclamation activities (e.g., reservoir filling and increased water availability) peaked in the 1960s downstream users in the lower basin began to notice.

By 1970 Colorado River users from the United States and Mexico were raising concerns over salinity. Levels of 800<sup>1</sup> ppm (as TDS) and

higher were becoming the norm in California and Arizona irrigation water, rendering it harmful to many crops. The formation of the Environmental Protection Agency and a fear of being regulated with state-line limits encouraged the seven basin states to work with federal agencies to draft special salinity legislation for the Colorado River. In 1974, the Colorado River Basin Salinity Control Act was passed by Congress.

The act was amended several times (1984, 1995, 1996, and 2008) and now exists as the Colorado River Basin Salinity Control Program, or “Salinity Program.” The Salinity Program is a unique and successful collaboration<sup>2</sup> between the Department of Interior (Bureau of Reclamation, Bureau of Land Management, and the Geological Survey), the Department of Agriculture (Natural Resources

<sup>1</sup> Drinking water typically has <500 mg/L TDS and Seawater >30,000 mg/L TDS. Most crop damage starts to occur once water in the root zone reaches 700 mg/L TDS or higher – this is often a function of soil and water salinity.

<sup>2</sup> There are three stakeholder groups that manage and inform the Salinity Program: the Salinity Forum—the basin states representatives; the Federal Advisory Committee—where the forum and federal agencies consult on federal salinity expenses; and the technical workgroup that advises the two policy-making groups.

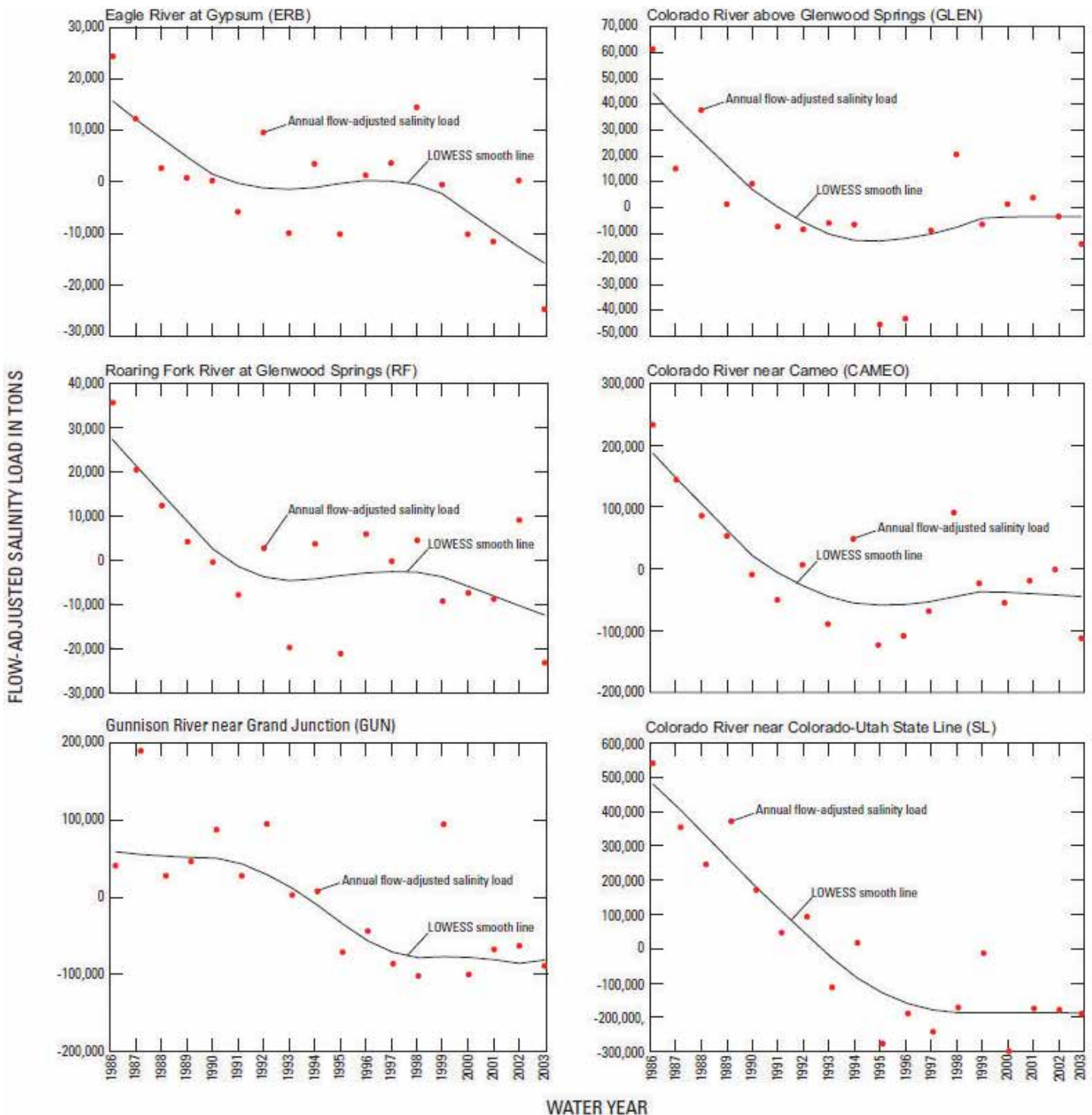


Figure 1. Flow adjusted (LOWESS curves) salinity loads from various gages on the Colorado River in Colorado showing the impact of the Salinity Program on levels of dissolved salt (TDS). Water Years 1986 to 2003.

Courtesy Leib and Bauch, USGS Scientific Investigations Report 2007-5288

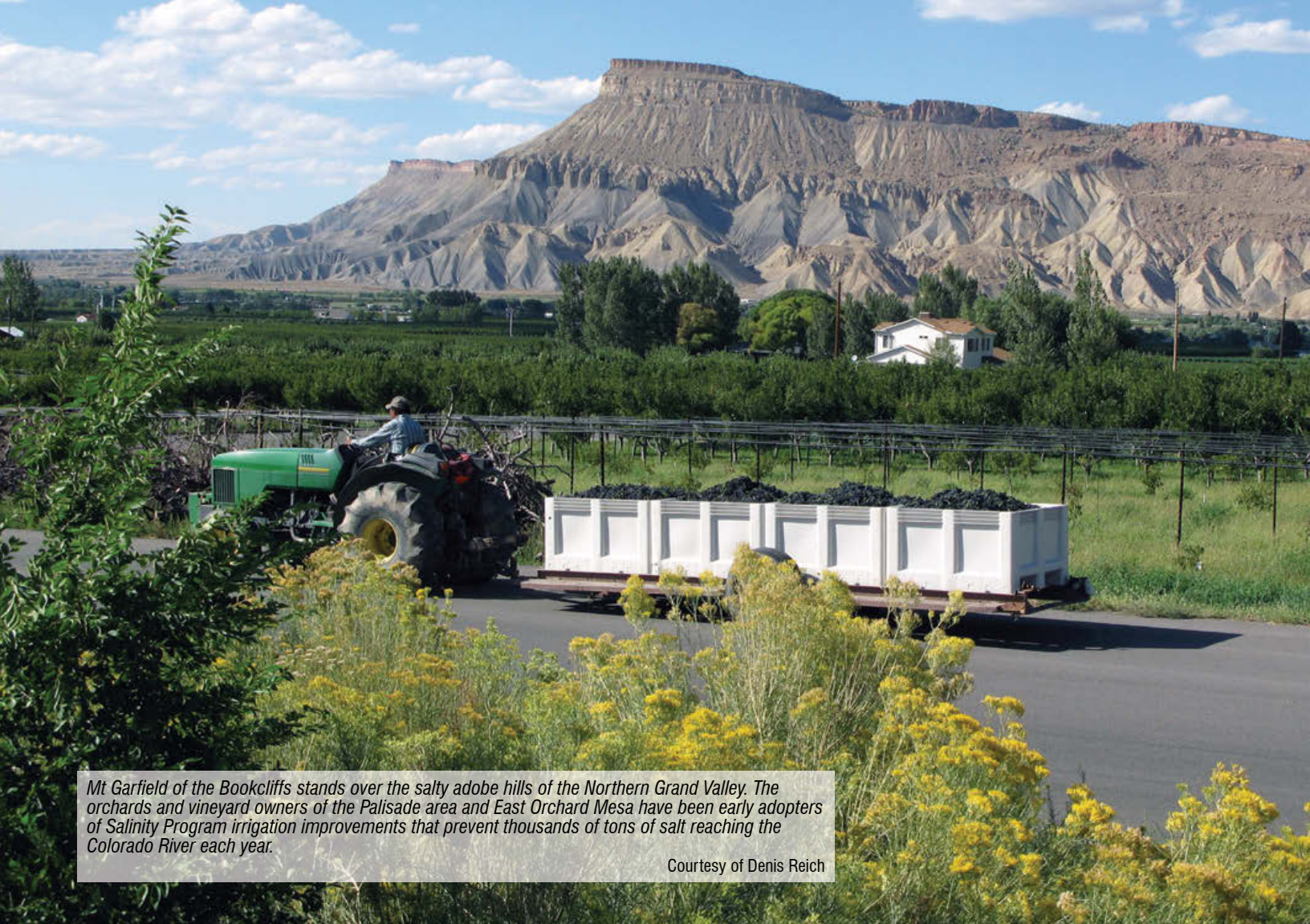
Conservation Service), the Basin States, and most importantly private landowners voluntarily participating in cost share and incentive payments.

In 2010 the Grand Valley Unit of the Colorado River Salinity Control Program achieved its target of 132,000 tons per year of salt prevented

from reaching the river through on-farm irrigation improvements. This represents 30 years of sustained effort on the part of Colorado's Natural Resources Conservation Service (NRCS) and key partners like Reclamation. Recently retired Assistant State Conservationist Frank

Riggle has had more experience than most when it comes to on-farm salinity control.

"The Salinity Program is unique," says Riggle. "I don't think there's another water quality program anywhere that has seen this amount of work done across such a large area for this long



*Mt Garfield of the Bookcliffs stands over the salty adobe hills of the Northern Grand Valley. The orchards and vineyard owners of the Palisade area and East Orchard Mesa have been early adopters of Salinity Program irrigation improvements that prevent thousands of tons of salt reaching the Colorado River each year.*

Courtesy of Denis Reich

a period with such a significant and measureable impact. Quite a feat,” he continues, “for a river the size and magnitude of the Colorado” (see Figure 1). The Program’s success has since become a model for public/private partnerships tackling large scale natural resource problems.

In addition to the nonpoint source problem, some of the larger point source salt problems have also been tackled by the program. Natural saline springs such as those used to feed the Glenwood Hot Springs Pool are the major salt contributors to the river. At the point of the program’s inception, nearly 10 million tons of dissolved salts were passing annually below Hoover Dam. The Salinity

Program has traditionally focused on mitigating the agricultural portion of this load. Irrigation on the eastern edges of the Colorado Plateau is responsible for almost half of the salt contributions to the system.<sup>3</sup>

The largest point source project completed so far is the Reclamation owned and operated deep well brine injection system near Paradox, Colorado. It is estimated that the Paradox injection well project successfully prevents approximately 110,000 tons of salt per year from entering the Colorado River system by capturing shallow saline groundwater that is tributary to the Dolores River and disposing of this brine over 14,000 feet below the surface into a

geologically confined layer. However, the injection well is now approaching or even exceeding its design life, and the receiving zone is close to full, which is reflected in increasing pumping pressures needed to bury the offending water. Whether to drill a second well in a new location or try a new strategy such as membrane treatment and evaporation ponds is under consideration via an alternatives NEPA analysis being performed by Reclamation.

In a sense the Salinity Program is now at a crossroads. “The low hanging fruit has already been picked,” reflects MaryLou Smith of the Colorado Water Institute. Smith is a subcontractor with URS Engineering on a

<sup>3</sup> The Environmental Protection Agency has identified that 62 percent of the salt load contributions into Hoover Dam are from natural sources.



new multidisciplinary project, "Comprehensive Planning Studies for Salinity control measures in the Upper Colorado River Basin." Working with URS Engineers under the leadership of Dave Merritt, Smith is interviewing farmers and identifying barriers to user participation in remaining cost effective salt control projects. "By learning more about what is preventing some

farmers and irrigation companies from participating in the Salinity Program, administrators will have the opportunity to tweak the program for improved impact," says Smith.

The rising cost of salt control clearly underlies many of the obstacles to participation. "Western Colorado agricultural producers and water users have benefitted from the Salinity Program, but moving forward in the era of financial constraints is quite a challenge" observes Dave Kanzer, Colorado River District Senior Water Resources Engineer and Salinity Program workgroup member. "Therefore, we anxiously await results from the 'planning studies' project to help us improve the implementation and success rate of the Salinity Program. It's a program that is essential to wise water use in the Upper Colorado River basin," concludes Kanzer.

Steve Gunderson, Director of the Water Quality Control Division at the Colorado Department of Public Health and Environment agrees. "The Salinity Program has not outlived its usefulness," says Gunderson. "The Lower Basin states are still very much invested in Salinity mitigation and in the Upper Basin we have come to depend on the multiple benefits of the Salinity Program such as Selenium control." In a sense selenium is the new salinity. Found with mineralized salt in some shale soils, it's highly concentrated in Western Colorado, particularly the Lower Gunnison Basin. It contaminates the river at very low concentrations, not harmful to crops or humans, but surprisingly destructive to many forms of aquatic life, some of which are endangered. Thanks in part to salinity program funded control projects, concentrations of dissolved selenium are dropping towards, and in some cases even below, the state standard of 4.6 parts per billion.

Thanks to its continued success, the Salinity Program continues to be a benchmark for water quality programs across the United States and around the globe. While funding to other natural resources collaborative processes are particularly vulnerable given the current economic climate, the Salinity Program has found ways to adapt and remain viable in spite of these pressures. In 2013 there will be a celebration in Grand Junction for the Grand Valley exceeding its target for removal. It should be the first of many to come.

## Acknowledgements

Thanks also to Travis James of NRCS in the Salt Lake Reclamation office, and Terry Stroh and Dan Crabtree of the Bureau of Reclamation Upper Colorado Regional Office in Grand Junction for their assistance with this article.



*Bad experiences with the first pivot sprinklers in the 1980s have delayed adoption of newer technologies among row-crop farmers in the salt affected areas of the Upper Colorado. This producer adjusts an emitter on a more modern pivot, which runs on lower pressures—around 30 psi—producing smaller droplet sizes, which greatly improves infiltration and crop water uptake.*

Courtesy of Denis Reich

# The Colorado River District and Its First 75 Years

George Sibley, Freelance Writer and Editor

**W**ater Wranglers, *The 75-year History of the Colorado River District: A Story About the Embattled Colorado River and the Growth of the West* is the story of the first 75 years of the Colorado River District—more formally known as the Colorado River Water Conservation District, guardian of Colorado’s share of the Colorado River. To understand the role of the River District in Colorado’s history, one has to look closely enough at the history of water development in the West to understand that the physical infrastructure for water use—the dams and reservoirs, canals and ditches—is underlaid by a much more complex legal, political, economic, and social infrastructure.

That less visible infrastructure for water development in Colorado took a giant step toward coherence 75 years ago, in 1937, when the Colorado General Assembly passed legislation creating three new water agencies:

- The Water Conservancy Act enabled the creation of quasi-municipal taxing districts to develop major water projects with the Bureau of Reclamation and to enable repayment of the local share of the cost of constructing those projects. This led within months to the creation of the Northern Colorado Water Conservancy District (now Northern Water) to facilitate construction of the Colorado-Big Thompson Project, the first large transmountain diversion from the Colorado River Basin to Colorado’s East Slope of the Continental Divide.
- The Colorado Water Conservation Board was created to implement an “All-Colorado” water plan that had been sketched out by Colorado’s State Planning Commission in 1935. This was also created to

help the state to better access federal “New Deal” assistance. The federal government would only help states that had a high level of statewide unity on potential federal projects—not an easy thing to achieve between the West and East Slopes of the Continental Divide in Colorado.

- The Colorado River Water Conservation District—the River District—was created to protect and develop Colorado’s share of the Colorado River (serving six other states, including the giant California), with the additional task of ensuring that Coloradans west of the Continental Divide got the use of a reasonable portion of Colorado’s share.

By the 1930s, both the South Platte and Arkansas Rivers east of the Continental Divide had been over-appropriated, and Denver had been growing vigorously. It was apparent that most future water development for those most populated and developed parts of Colorado would involve transmountain diversions, bringing water from Colorado River tributaries west of the Divide into those two East Slope basins. The City and County of Denver was already at work on such a diversion by the mid-1930s, to bring Fraser River water through the Moffat Tunnel pilot bore, and within a few weeks of the close of Colorado’s 1937 General Assembly, the United States Congress had appropriated its first funding for the Colorado-Big Thompson Project.

Those two projects—Denver’s Moffat Tunnel diversion and the South Platte farmers’ Colorado-Big Thompson—set the “bi-polar” tone for many 20th century River District interactions with Colorado water users east of the Divide. On the one hand, the Colorado-Big Thompson Project had been worked

out among agricultural users on both slopes to be ultimately beneficial to both slopes. Part of the South Platte farmers’ obligation would be repayment for the Bureau’s construction of Green Mountain Dam and Reservoir on the West Slope, “compensatory storage” to insure that the diversion of water out of the Colorado River Basin would not constrain future development on the West Slope. On the other hand, Denver’s diversion had been undertaken with no consultation with anyone on the West Slope and no concern for future consequences there, leading to half a century of pitched courtroom battles with rapidly expanding Front Range metropolitan utilities.

In addition to being the story of both cooperative and contentious transmountain diversion projects, *Water Wranglers* is the story of interactions, some cooperative and some contentious, with the other six states with interests in the Colorado River: a “Lower Basin” including California, Arizona, and Nevada; and an “Upper Basin” including Utah, Wyoming, and New Mexico (as well as Colorado). Again, a complex legal and political infrastructure of interstate compacts and federal legislation were foundational to the physical development of most of the Colorado River’s water, from the 1922 Colorado River Compact through the Colorado River Basin Project Act passed in 1968.

The Colorado River Storage Project (CRSP), passed by Congress in 1956, resulted in half a dozen federal structures within the River District’s purview and the unfulfilled promise of many more. But it also created new tensions with Colorado east of the Divide—concerns that CRSP development might consume all of Colorado’s remaining share of the Colorado River



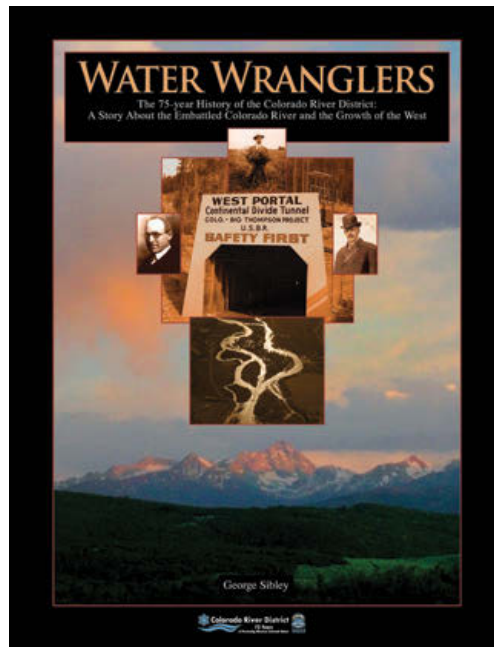


Clifford Stone was an early leader of the Western Slope Protective Association that later became the Colorado River Water Conservation District (Colorado River District). He was later the first director of the Colorado Water Conservation Board. Courtesy of the Colorado River District

resulted in a “filing war” between the River District and the Front Range utilities; Denver’s Water Board passed a resolution to file on all the unappropriated water on the West Slope down to the junction of the Colorado and Eagle Rivers. Each side’s diligence hearings on its filings were opposed by the other side in an expensive war of attrition. This continued until the mid-1980s, at which point Denver’s Water Board began to acknowledge the legitimate needs and concerns of the River District and West Slope.

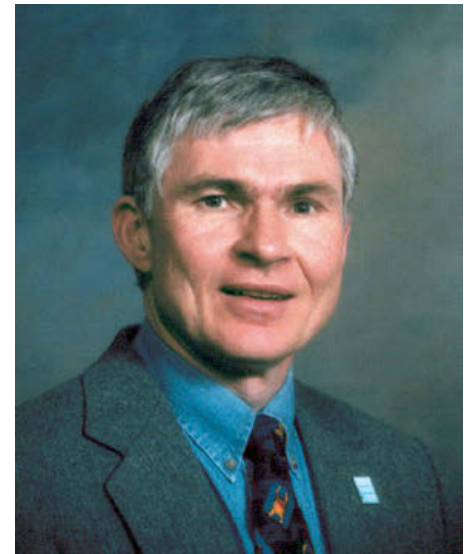
While that contention was going on in Colorado, the nation was undergoing a major philosophical and political shift that began to impact the River District. Prior to World War II, the nation still generally accepted the West’s reclamation project as a national priority—a cultural mandate to stop “wasting” the snowmelt waters of the arid-lands rivers in a two-month runoff flood, by storing those waters for use throughout a growing season, and also for use by the West’s growing cities and industrial capacity.

After World War II, however, the urbanizing, industrializing nation



began to look at the West differently. The old American dream of an agrarian paradise faded for a nation no longer made up of farmers or their near descendants; the automobile made the natural wonders of the West accessible to people whose jobs included a couple weeks of vacation time. The concept of “conservation” changed from “conserving” a resource like water for human use rather than “wasting it” to the ocean, to “conserving” it from human use outside of the riverbed in order to leave more water in the river for fishing, boating and other recreations.

This change in American political and economic priorities was reinforced in the late 1960s and early 1970s by the full flowering of an “environmental” revolution—a huge public rejection of the all-out industrial conversion of the nation’s natural resources to consumer goods, with all negative consequences of massive industrialization externalized to taxpayers. Strong and somewhat punitive laws were passed circa 1970 to reverse those negative consequences—the National Environmental Policy Act, which required expensive studies of all federal actions impacting the physical environment; the Endangered Species Act; and an ever-stricter Clean Water Act.



Eric Kuhn is the General Manager of the Colorado River District. Courtesy of the Colorado River District

This too became part of the River District’s story: four species of fish unique to the Colorado River were discovered to be endangered, and after some initial footdragging, the River District has taken on the complex challenge of saving the fish without shutting down water development on the Colorado and its tributaries.

These stories are underlaid by an even more fundamental “problem of democracy”: the West Slope has roughly one tenth of Colorado’s population; how does a one-to-nine minority assert its right to exist in a democracy in which “the majority rules,” and resource development takes place under the maxim of “the greatest good for the greatest number” (with “for the longest time” occasionally noted but seldom understood)?

All of these things are part of the story of the River District, as told in *Water Wranglers*—a story that comes up to the present with a River District that has mostly shed its old agrarian and utilitarian ideologies, and is attempting to look pragmatically and creatively at an increasingly complex water situation from a problem-solvers’ perspective.

# Drought Early Warning System for the Upper Colorado River Basin

*Nolan Doesken, Rebecca Smith, and Wendy Ryan, Colorado Climate Center,  
Department of Atmospheric Science, Colorado State University*

The Colorado River drains very large and primarily arid to semiarid regions of western Colorado and the southwestern United States. Most of the water in the river originates as high elevation snowpack from winter and spring snow accumulation from relatively small areas of the basin. The water availability limitations of the Colorado River Basin are well known and well studied. The development of irrigated agriculture utilizing Colorado River water, and the growth of large population centers in and near the basin in the last half of the 20th century, place high expectations for a reliable water supply from this watershed. Yet, variability in precipitation and runoff from one year to the next across this basin is remarkably large, as evidenced by the rapid transition from heavy precipitation and abundant water supplies in 2011 followed immediately by widespread and regionally extreme drought in 2012. (Figure 1) Large reservoirs throughout the basin smooth out some of this extreme hydrological variability for agricultural, municipal, industrial, and recreational water users. The extensive forest and

rangeland ecosystems of the basin do not have the benefit of this managed buffer.

A sharp downward trend in water reserves in Lake Powell, Lake Mead, and the smaller upper basin reservoirs beginning after 2000 along with projections for long term increases in regional temperatures and evaporation rates caught the attention of planners, policy makers, and resource managers across Colorado and the Southwest. The vulnerability of regional water supplies and the potential long-term impacts from drought led to a call to action from the Western Governors Association (WGA) for greater drought preparedness. This helped lead to the creation of the National Integrated Drought Information System (NIDIS) in 2006 (<http://www.drought.gov/drought/content/what-nidis>). The Upper Colorado River Basin was selected as the first of several NIDIS pilot projects to begin designing and implementing a drought early warning system. Work began in 2008.

The Colorado Climate Center has worked closely with the NIDIS program office to improve drought

monitoring and information exchange. The following paragraphs describe some of the activities and accomplishments of the past few years and challenges that have been encountered.

## Activities and Progress

### Stakeholder Engagement

Over a period of approximately one year, we met with a few dozen stakeholders whose activities are affected by drought in the Upper Colorado River Basin. Stakeholders ranged from municipal and agricultural water providers in the basin and along the Front Range (who rely on transmountain diversions from the Colorado River) to local government officials, consultants, and state and federal land/resource managers. Based on hours of discussions, we compiled a list of “information needs” and “monitoring gaps.”

### Needs Assessment

Stakeholders shared suggestions on the types and timeliness of data and information that would aid them in planning and decision making to

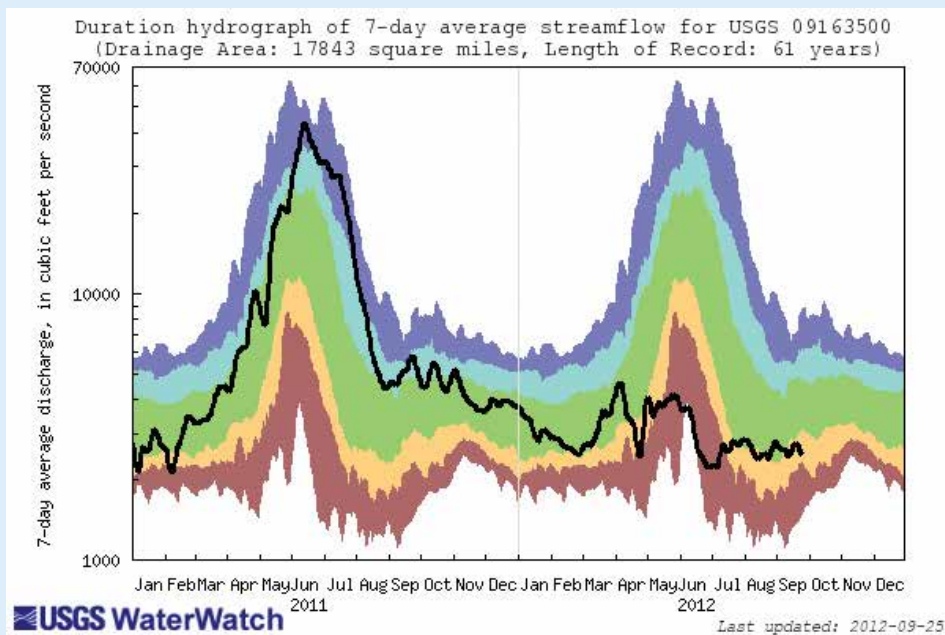


Figure 1. Streamflow on the Colorado River near the Colorado-Utah state line, showing the high variability and sensitivity of water supplies—this compares a very high peak flow in 2011 after a winter with extremely high snowpack followed by 2012, a year with very low peak flow after a winter with extremely low snowpack.

reduce the impacts of drought. Most stakeholders already accessed various types of climate and water resources data sources to provide early indications of future drought, but nearly all stakeholders thought there was considerable room for improvement, such as more timely and personalized information specific to their areas (smaller watersheds) with emphasis on snowpack, streamflow, reservoir levels, and future climate projections. Nearly all stakeholders were familiar with the U.S. Drought Monitor (USDM) as an up-to-date source of national drought information, but few found it to be a credible depiction or projection for their local conditions. A common theme was the desire for “One stop shopping” where there could be a single source for the bulk of the drought information.

Sublimation losses from snowpack, especially during years with dry, warm springs, have been an area of concern since 2002. Thanks to NIDIS funding, a graduate student at Colorado State University is currently conducting a modeling study of interannual and spatial variability in

snow sublimation. He should have results by early 2013.

Stakeholders who utilize or manage water from large reservoirs in the basin were particularly concerned about long-range forecasts. They were confident about their ability to manage a one-year drought, but very uncertain about drought management for droughts lasting three years or longer. Help anticipating long-term drought is greatly needed. Reservoir managers also appealed for more information regarding improved forecasts of peak flows during high runoff periods. How peak flows are managed within the various reservoir systems has considerable bearing on the amount of water that can be stored and retained for later use during dry years.

### Monitoring Gaps

Each group interviewed was asked what data and information was missing or inadequate to address their needs. These findings were reported in our article in the April/May 2011 issue of Colorado Water. Many groups had specific suggestions on locations where new Natural

Resources Conservation Service (NRCS) SNOTEL stations would likely improve local water supply forecasts (see Figure 2 for an example SNOTEL reading). These suggestions were submitted to the NRCS Snow Survey. Several additional sites have since been deployed.

Many other constructive suggestions were made, including improvements in tracking snow sublimation, more thorough observation of mid-elevation snow accumulation, and better gauging of smaller streams that may give a more accurate depiction of native flows.

In 2009, few stakeholders were utilizing remote sensing for snow monitoring and hydrologic prediction, but considerable progress in that area has subsequently been made. The Snow Data Assimilation System (SNODAS) integrates ground observations with remote sensing and is growing in skill and popularity for assessing snowpack and projecting water supplies.

### U.S. Drought Portal

The request for “one stop shopping” is gradually being achieved through the U.S. Drought Portal (<http://www.drought.gov>).

### Colorado Basin River Forecast Center (CBRFC) Stakeholder Engagement

Since our field interviews with stakeholders in 2009, the CBRFC in Salt Lake City has made great strides in improving stakeholder engagement and meeting specific stakeholder needs. Webinars are held each month throughout the snow accumulation season, providing sub-basin specific streamflow forecasts and uncertainty estimates. Information is much more accessible to users than in the past. Peak flow project updates are also provided. The CBRFC also holds an annual stakeholder meeting to

specifically work with their users to improve products and services.

### Enhanced Monitoring, Coordination, and Outreach—Weekly Webinar/Climate Water Assessments

The Colorado Climate Center, with the help of the NIDIS program office, first tested and subsequently operationalized a weekly update cycle. This activity directly addresses the need expressed by many stakeholders in 2009 for “more timely and locally interpreted information.”

We begin each week by summarizing recent precipitation, snowpack changes, streamflow, reservoir storage, temperatures, and evaporation rates. U.S. Geological Survey (USGS) hydrologists and NRCS Snow Survey sometimes assist in this effort. National Weather Service meteorologists from forecast offices in and near the Upper Colorado

River Basin pitch in with forecast information. Becky Smith (Ph.D. student and Drought Coordinator for the project) then assembles a short summary report that is circulated to a few dozen information providers within the basin by approximately noon each Tuesday. Input is gathered and then by Tuesday afternoon, a set of recommendations for updating the USDM maps for our region is sent to the USDM weekly author and then distributed to a list of several hundred subscribers. From mid January to mid summer, we also conduct weekly webinars summarizing this information for online participants.

Based on the experience of 2012, this weekly update process allowed us to closely track and assess developing extreme drought conditions. Unlike 2002 where there was a sense of being caught by surprise, in 2012 there was no doubt where and when conditions were deteriorating (Figure 3 Lake

Powell measurements show 2002 drought and recovery).

At the end of this article are instructions on how to access and/or participate in this weekly monitoring process.

### Seasonal Prediction

As we get better with other aspects of drought monitoring and information delivery, the area that now stands out is the extreme interest in accurate long-range prediction. NOAA has recently organized a NOAA Drought Task Force specifically to coordinate ongoing drought prediction activities. Here in the Upper Colorado River Basin, Klaus Wolter with the Cooperative Institute for Research in Environmental Sciences at the University of Colorado is working with NIDIS and the Upper Colorado River Basin Drought Early Warning System providing locally specific and annotated seasonal forecasts updated

several times a year. These forecasts are integrated within our weekly webinar series, and often attract much higher attendance.

### Challenges

Now that we are several years into the development and implementation of a Drought Early Warning System, some specific challenges include the following.

- Maintaining high quality monitoring of hydrometeorological processes in the face of shrinking budgets is difficult. We’ve made progress in the past few years, but holding this ground may not be easy. For example,

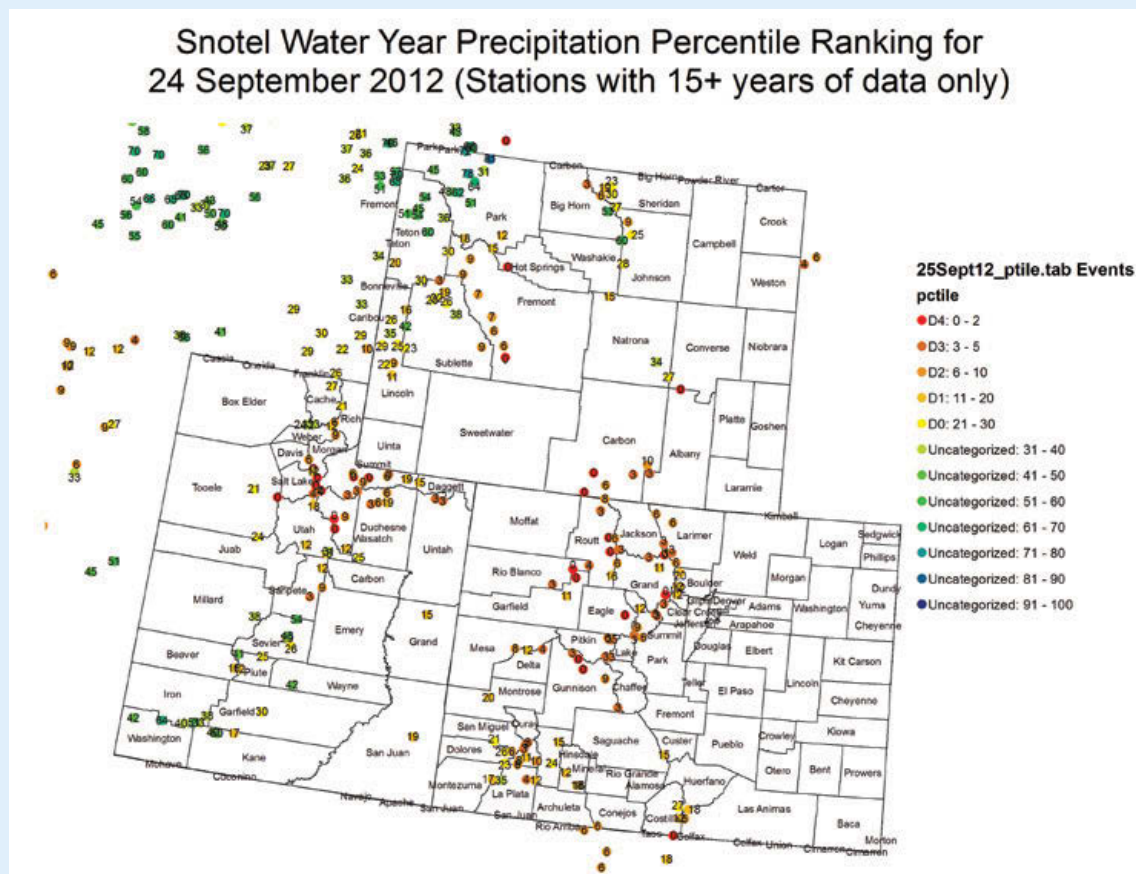


Figure 2. NRCS SNOTEL stations and their precipitation percentile rankings from October 1, 2011 - September 24 2012. Percentile rankings allow us to apply information directly to the U.S. Drought Monitor maps.

the National Weather Service has considered closing some long-term Cooperative Stations and possibly reducing or eliminating the network of automated stations deployed in response to the 1983-1984 floods. NRCS has their hands full maintaining the SNOTEL system. Our office continues to struggle for adequate resources to maintain high quality evapotranspiration measurements from the Colorado Agricultural Meteorological Network (CoAgMet). There is much data being collected now—more than in 2002. But maintaining quality long-term data collection will always be a struggle.

- Coordination of monitoring efforts across state lines
- Communicating drought severity without inadvertent negative impacts on recreation and tourism interests (possibly a topic necessitating further conversation)
- Providing an accurate and consistent portrayal of drought severity on a single map—the USDM—recognizing the differing scales of drought and how differently drought effects different economic sectors (such as irrigated versus dryland agriculture)
- Seasonal climate prediction—while this has become one of the most requested types of information by many stakeholders in the basin, accurate prediction from weeks, months or years in advance remains elusive. Robin Webb (NOAA – Boulder) recently provided a summary of 10 years of progress in seasonal prediction at the 2012 Colorado Drought Conference. Progress has been made but has not yet resulted in forecasts with sufficient skill to guide many long-range decisions.

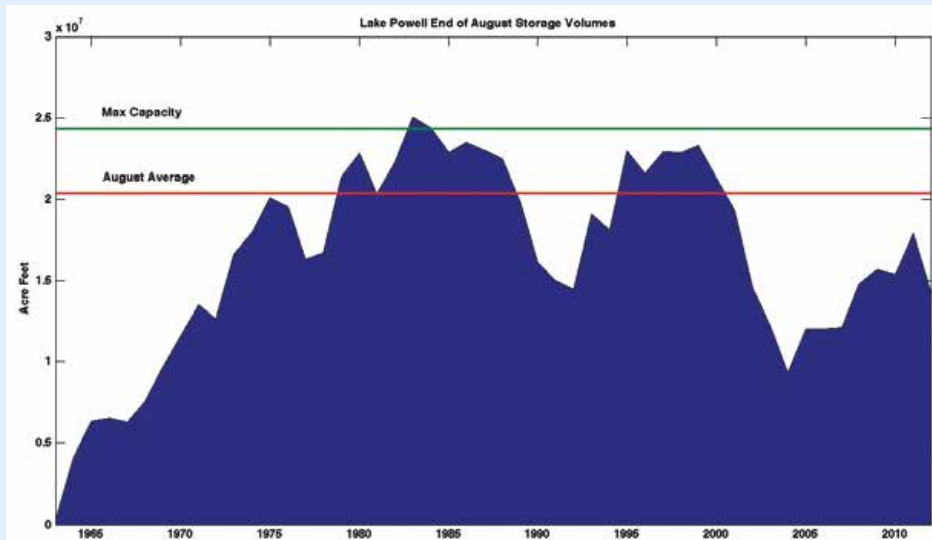


Figure 3. Reservoir levels at Lake Powell at the end of August through time. It shows the large drop in the level around 2002 (an extreme drought period for much of the southwest) and its slow response at increasing levels again.

- Others—please feel free to contact us with suggestions and concerns where you feel hydrometeorological monitoring and prediction services are not meeting your needs.

### Summary

For now, the best “Drought Early Warning System” is a comprehensive monitoring program that tracks current hydrometeorological conditions so we know very well how much we have in our buckets and how this compares to our expectations for this time of year. We’ve made a lot of progress and we will continue to make improvements.

### Opportunities to Participate

When it comes to drought monitoring and early warning, we all have expertise that adds to the understanding of drought and its impacts. Our weekly “Climate, Water and Drought” assessments are open to the public. Archived assessment reports for the past three years are available at [http://ccc.atmos.colostate.edu/drought\\_webinar.php](http://ccc.atmos.colostate.edu/drought_webinar.php).

If you would like to receive an email each week when the assessment report is completed, please contact

Henry Reges:  
[hreges@atmos.colostate.edu](mailto:hreges@atmos.colostate.edu).

### CBRFC Webinars

You are also welcome to participate in our interactive drought monitoring webinars. These are approximately 30 minutes in length and are held from mid January to mid summer each year and occasionally from August to December as conditions warrant. To register: [http://ccc.atmos.colostate.edu/drought\\_webinar\\_registration.php](http://ccc.atmos.colostate.edu/drought_webinar_registration.php)

Alternatively, send Henry an email and he’ll put you on the webinar announcement list.

Please make use of U.S. Drought Portal, [www.drought.gov](http://www.drought.gov). It contains a wealth of information. If you have comments or suggestions regarding the content and function of this portal, please let us know so we can pass on your recommendations.

Finally, infrequent but in-depth stakeholder meetings are held to facilitate face-to-face discourse on drought planning. If you or your organization would like to be involved at this level, please contact Jim Verdin at [verdin@usgs.gov](mailto:verdin@usgs.gov).

# Unique Perspectives on Colorado River History

Patricia J. Rettig, Head Archivist, Water Resources Archive, Colorado State University Libraries

*“There is no dearth of problems concerning this river. At times, chaos and confusion appear to be predominant.”*

– Ival V. Goslin, in 1971 speech titled “Colorado River Situation”

Ival Goslin gave many speeches in his role of managing the Upper Colorado River Commission. He had a unique perspective on the Colorado River, as did many others working on the various issues surrounding the river and its use. Speeches, letters, diaries, reports, and more from these kinds of people provide the raw materials of history. When they are made available through archives, all people have the opportunity to benefit from them.

The Water Resources Archive at Colorado State University collects and preserves such materials to document water resources development and use across the state and the West. Because of the importance of the Colorado River in the region, inevitably many of the materials collected relate to that river and its tributaries. Several important collections at the Archive contain substantial documentation on the Colorado River. Those highlighted here represent just a few of the diverse legal, management, engineering, and environmental perspectives documented.

## Legal Perspective: Papers of Delph E. Carpenter and Family

When seven western states agreed to negotiate how to share the Colorado River, water law took a historic turn. Commissioners from those states, including Colorado’s Delph Carpenter—known as the father of interstate river compacts—drafted a compact in 1922. The 12-page document that resulted, the Colorado River Compact, has thousands of pages of drafts, letters, meeting minutes, data, reports, maps, and articles related to it. These materials, along with Carpenter’s diaries and about 200



*Intake structure for the Blue Mesa Dam, Gunnison River, October 1964 (Ival V. Goslin Collection). Both Ival Goslin and Robert Glover took hundreds of photos of Colorado River structures.*

Courtesy of the Water Resources Archive, Colorado State University Libraries

contemporary newspaper articles, are available for anyone to track the fights and compromises that now govern the use of the Colorado River. Hundreds of the pages are available digitally through the Water Resources Archive website.

## Management Perspective: Ival V. Goslin Water Resources Collection

From 1955 through 1979, Ival Goslin served as the executive secretary of the Upper Colorado River Commission. He was responsible for administering the Upper Colorado River Compact (1948) for the states of Colorado, New Mexico, Utah, and Wyoming. During this time, he worked with Congressman Wayne Aspinall on the Colorado River Storage Project. Goslin’s speeches, legislative committee hearings, and reports from various agencies best reflect his involvement in that project. Most of his speeches are digitized and available online.

At the end of his career, from 1982 to 1985, Goslin served as the first executive director of the Colorado Water Resources and Power Development Authority, and after that as a special consultant. The Authority conducted a number of feasibility studies to find potential projects to finance, and these

studies and related documentation make up the bulk of Goslin’s collection. Studies concerning many of the Colorado River’s tributaries, as well as transmountain diversion projects involving the river, provide an extensive examination of the water planning process. A selection of these studies have been scanned and posted online.

## Engineering Perspective—Dams: Papers of Robert E. Glover

Robert Glover had a distinguished career with the Bureau of Reclamation from 1920 until 1954, the height of the Bureau’s dam building period. His extensive work on Hoover Dam in the 1930s led to the development of a refrigeration system to accelerate concrete cooling. He also worked on Flaming Gorge, Glen Canyon, Davis, and Parker dams, all in the Colorado River Basin. Glover’s project files for much of this work survive and contain mostly letters, reports, calculations, notes, and drawings about the structure of these dams and their construction. The accumulation of technical data gives insight into the challenges engineers meet. Many of Glover’s files related to his work in the Colorado River Basin are digitized and online.

## Engineering Perspective—Irrigation: Papers of Marvin E. Jensen

A significant contributor to the development of improved methods in estimating irrigation water requirements, Marvin Jensen spent most of his career working for the U.S. Department of Agriculture (1955-1987) and doing extensive consulting work. The materials he has donated so far to the Archive document two projects he worked on to evaluate water distribution and usage along the lower Colorado River. His archival

collection includes data, correspondence, notes, and reports dealing with each project, one evaluating the Lower Colorado River Accounting System (LCRAS) and the other evaluating Colorado River water usage within California's Imperial Irrigation District. Though the Archive has not yet digitized any of these materials, the Bureau of Reclamation's Web page about Lower Colorado River Water Accounting contains links to yearly LCRAS reports, some of which were written by Jensen.

## Environmental Perspective: Papers of Mark W. T. Harvey

The Colorado River Storage Project of the 1950s originally included the proposed construction of a dam just downstream from Echo Park, an area on the Green River in Dinosaur National Monument, located in northwestern Colorado and northeastern Utah. After a lengthy political battle between conservation groups and Western congressmen, the proposal was defeated and the dam was never built. That environmental victory had significant implications for the conservation movement in the United States.

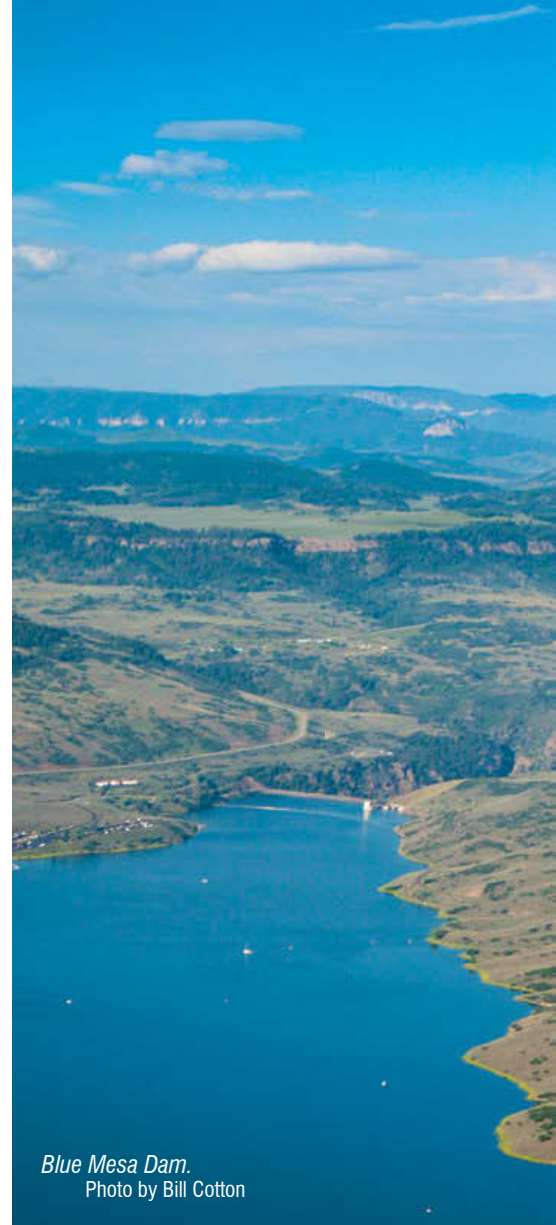
Mark Harvey, professor of history at North Dakota State University, wrote *A Symbol of Wilderness: Echo Park and the American Conservation Movement* (1994), a book which explores the controversy of the proposed dam. The materials in his collection were either collected or created by him in relation to his book, providing an excellent accumulation of copies of documents from around the country on this important topic.

## More Perspectives


Several additional collections in the Water Resources Archive document the Colorado River basin in important

ways, but to a lesser extent than those detailed above. The Papers of Robert K. Davis document his work on salinity and other issues in the Lower Colorado River Basin. Though Charles Fisk's book concerns Denver Water, issues documented there and in his research materials relate to the Colorado River. Like Goslin, Gilbert G. Stamm, commissioner of the U.S. Bureau of Reclamation (1973-1977), gave a number of speeches related to the Colorado River. Beyond papers, Stamm, Goslin, Glover, and others have numerous photographs of the river and its engineered features as well.

All of these collections and more make the Water Resources Archive a great place to do historical research on the Colorado River. To keep unique perspectives on this important basin from slipping away, the Archive is interested in preserving additional collections of historical importance. For more information about all of the collections in the Water Resources Archive, as well as how to donate materials, see the website (<http://lib.colostate.edu/water/>) or contact the archivist (970-491-1939; [Patricia.Rettig@ColoState.edu](mailto:Patricia.Rettig@ColoState.edu)) at any time.



Blue Mesa Dam.  
Photo by Bill Cotton

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Send the following message, subject to the terms on back hereof, which are hereby agreed to

January 20, 1922

Hon. Thomas E. Campbell  
Governor of Arizona  
Phoenix, Arizona.

You are hereby notified that pursuant to Chapter two hundred forty six Session Laws of Colorado nineteen twenty one on May ninth nineteen twenty one Delph E. Carpenter of Greeley Colorado was duly appointed commissioner for Colorado thereunder to negotiate a compact between Colorado and the United States and the other Colorado River states mentioned in Section one of said Act and that his commission was delivered and he duly qualified as said Commissioner on the said date.

O. H. Shoup  
Governor of Colorado

Chgo Governors Office.

*Telegram confirming Delph Carpenter's appointment as Colorado River commissioner, January 20, 1922 (Delph Carpenter Papers). Thousands of pages trace the ensuing compact negotiations and outcomes.*

Courtesy of the Water Resources Archive, Colorado State University Libraries

Probability and volume of potential postwildfire debris flows in the 2012 Waldo Canyon Burn Area near Colorado Springs, Colorado; 2012; Verdin, Kristine L.; Dupree, Jean A.; Elliott, John G. USGS Open-File Report: 2012-1158

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# Christopher A. Bareither

Lindsey A. Middleton, Editor, Colorado Water Institute

Colorado State University welcomes Christopher Bareither this Fall 2012, an Assistant Professor in the Department of Civil and Environmental Engineering.

Bareither holds a Bachelor of Science in Geological Engineering from the University of Idaho, and a Master of Science and doctorate in Geological Engineering from the University of Wisconsin-Madison (UW).

He is teaching one class this semester—CIVE 355, Introduction to Geotechnical Engineering. Bareither taught a similar course at UW during Spring 2012 and developed a “blended” version of the course that was offered this past summer. The blended course coupled online lessons with in-class problem-solving sessions. He is currently working with a Ph.D. student at UW to evaluate the effectiveness of blended education in undergraduate engineering education.

“I enjoy teaching—I like the flexibility you have as a professor,” says Bareither of his decision to pursue a career in the academic field. This enjoyment of teaching and desire for flexibility also stemmed from his involvement in Engineers Without Borders (EWB) during his time at UW. Bareither served as a member, project manager, and project mentor on a wastewater infrastructure project in El Salvador from 2005-2012, during which he visited El Salvador five times. He plans to continue his commitment to service and plans to become involved with the EWB chapter at CSU in the future.

Bareither plans to continue his graduate and post-doctoral research at Colorado State University, which included both geoenvironmental and geotechnical research. For his master’s degree, Bareither sampled and



characterized 30 naturally occurring sand and gravel deposits throughout Wisconsin and conducted direct shear testing to evaluate strength properties. Through soil characterization, geological origin, and shear testing, he identified regions with adequate and inadequate materials to be used for backfill by the Wisconsin Department of Transportation.

For his doctoral research, Bareither chose to work on the compression behaviors of municipal solid waste, towards creating predictive tools for bioreactor landfills. He focused mainly on compression and solids decomposition, with a slight focus on hydrology throughout the project. Bareither explains that such tools could allow landfill operators to predict, given the maximum air space limitations placed on landfills, how much waste they are able to deposit over time.

Bareither foresees future landfill research pointing toward how to effectively manage, reuse, and repurpose waste, as well as potential energy collection

in the form of methane or, if feasible, heat energy, which is given off by biological processes.

Along those research lines, Bareither hopes to establish a unique, innovative research program during his time at CSU. He says over the long term, he would like to help reinvigorate geotechnical and geoenvironmental programs at CSU.

Bareither is already on the Tailings and Mine Waste Committee, for which the annual conference was held in Keystone, Colorado in 2012. Bareither says it will be a great opportunity to become involved in the area and network with other professionals.

He plans to conduct research in mine waste, as well—Bareither already advises two students, one of whom is a master’s candidate whose research applies to tailings and mine waste. The other student is a PhD candidate who will conduct a comparative assessment of municipal solid waste settlement models. This work will take Bareither’s past experimental research on waste compression to the next phase, and provide landfill operators with a suite of tools for predicting waste settlement for different operational and environmental conditions.

**Christopher A. Bareither, PhD**  
Assistant Professor



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# Water Research Awards

Colorado State University (September 16, 2012 to November 15, 2012)

**Andales, Allan A**, Soil & Crop Sciences, USDA-Agricultural Research Service, Application of System Models to Evaluate and Extend Cropping Systems Studies at Different Great Plains/Northwest, \$120,000

**Bagley, Calvin F**, CEMML, DOD-ARMY-Corps of Engineers, Fog Oil - Clean Water Act Application Determination for Fort Wainwright, Alaska, \$65,000

**Bestgen, Kevin R**, Fish, Wildlife & Conservation Biology, DOI-Bureau of Reclamation, Identification & Curation of Larval & Juvenile Fish (Project No. 15), \$152,742

**Bowen, Richard A**, Clinical Sciences, DOS-Agency for International Development, Adapting Livestock Systems to Climate Change: A Global Approach, \$3,300,000

**Brozka, Robert J**, CEMML, DOD-ARMY-Corps of Engineers, Watershed Management Services at Fort McCoy, Wisconsin, \$226,716

**Brozka, Robert J**, CEMML, DOD-ARMY-Corps of Engineers, Fisheries and Wildlife Program Support at Fort A.P. Hill, Virginia, \$75,837

**Caldwell, Elizabeth D**, CEMML, DOD-ARMY-Corps of Engineers, Oil/Water Separator Evaluation, Joint Base Elmendorf/Richardson, Alaska, \$192,815

**Caldwell, Elizabeth D**, CEMML, DOD-ARMY-Corps of Engineers, Stormwater Pollution Protection Plan at Fort Leonard Wood, Missouri, \$50,000

**Clements, William H**, Fish, Wildlife & Conservation Biology, Colorado Division of Parks and Wildlife, Evaluating Restoration Effectiveness in the Arkansas River, \$49,402

**Cox, Amanda L**, Civil & Environmental Engineering, Urban Drainage & Flood Control District, Detention Pond Outlet Structure Model, \$8,942

**Hawkins, John A**, Fish, Wildlife & Conservation Biology, DOI-Bureau of Reclamation, Middle Yampa Smallmouth Bass & Northern Pike, \$300,692

**Hawkins, John A**, Fish, Wildlife & Conservation Biology, DOI-Bureau of Reclamation, Monitoring of Potential Colorado Pikeminnow Entrainment in the Maybell Canal, Yampa River, Colorado, \$4,089

**Johnson, James Bradley**, Biology, City of Aurora, Aquatic Mapping in the Arkansas River Headwaters Sub-Basin, \$5,000

**Johnson, James Bradley**, Biology, EPA-Environmental Protection Agency, Phase 2 of Building the Colorado Watershed Approach: A Strategic, Multi-Agency Approach to Development of Stream Mitigation Protocols and Aquatic Habitat Mapping, \$118,331

**Lemly, Joanna**, Colorado Natural Heritage Program, DOI-Bureau of Reclamation, National Wetlands Inventory Mapping for the Southern Rockies LCC, \$73,188

**McKay, John K**, Bioagricultural Sciences & Pest Management, USDA-ARS-Agricultural Research Service, The Role of Root System Architecture in Drought Tolerance, \$67,739

**Sanders, Thomas G**, Civil & Environmental Engineering, DOI-NPS-National Park Service, Water Rights Activity Assessment, and Water Rights Records Research and Management in Protection of Water and Aquatic Resources of Units of the Nation, \$4,000

**Winkelman, Dana**, Cooperative Fish & Wildlife Research, DOI-Bureau of Reclamation, Population Dynamics Modeling of Introduced Smallmouth Bass, Upper Colorado River Basin, \$70,000

# Calendar

## November

- 28-29 Colorado Aquifer Management: Groundwater and River Flow Connections; Denver, CO**  
American Ground Water Trust is organizing a two-day conference for water managers, end users, and their scientific and legal advisors on river accretions due to artificial recharge, stream depletions due to well pumping, and their impact on water management policy.

## December

- 4 Southwestern Water Conservation District Board Meeting; Durango, CO**  
For more information contact the SWCD at (970) 247-1302.  
[www.waterinfo.org/node/5610](http://www.waterinfo.org/node/5610)
- 10 Water Quality Control Commission Meeting; Denver, CO**  
Rulemaking Hearing and Business Meeting  
[www.colorado.gov/](http://www.colorado.gov/)
- 12-14 Colorado River Water Users Association Annual Conference; Las Vegas, NV**  
[www.crwua.org/](http://www.crwua.org/)

## January

- 15-17 Disasters and Environment; Science, Preparedness, and Resilience; Washington, D.C.**  
National Council for Science and the Environment presents the 13<sup>th</sup> National Conference on Science, Policy and the Environment  
[www.DisastersandEnvironment.org](http://www.DisastersandEnvironment.org)
- 30-1 Colorado Water Congress 2013 Annual Convention; Denver, CO**  
The event draws more than 500 attendees from across Colorado, including legislators, representatives of state and federal agencies, leading water attorneys, water resource managers, engineers, scientists, and a broad spectrum of water users.  
[www.cowatercongress.org/](http://www.cowatercongress.org/)

## February

- 11-14 Colorado Rural Water Association Annual Conference & Exhibition; Colorado Springs, CO**  
This year's conference on Water, Wastewater, Source Water, Groundwater, Management, and Operation Certification issues covers a wide range of programs with multi-simultaneous sessions.  
[coloradoruralwater.sharepoint.com/Pages/CopyHomePage.aspx/](http://coloradoruralwater.sharepoint.com/Pages/CopyHomePage.aspx/)
- 21-22 Stormwater & Urban Water Systems Modeling Conference; Toronto, Canada**  
Attend the 46<sup>th</sup> annual international conference and network with the industry's leading engineers, scientists, modelers and professionals.  
[www.chiwater.com/Training/Conferences/conferencetoronto.asp](http://www.chiwater.com/Training/Conferences/conferencetoronto.asp)

## March

- 2 Water Tables 2013; Fort Collins, CO**  
This year's theme, "Water in the West: Coping with Extremes" promises to be livelier than ever. The event starts at five p.m. with a reception and tours of the Archive at Morgan Library before moving to the Lory Student Center main ballroom for dinner.  
[lib.colostate.edu/archives/water/water-tables/2013/](http://lib.colostate.edu/archives/water/water-tables/2013/)

## April

- 15-17 NWRA Annual Conference; Washington, D.C**  
Theme: Federal Water Issues  
[www.nwra.org](http://www.nwra.org)

## September

- 15-18 28<sup>th</sup> Annual Watereuse Symposium; Denver, CO**  
The world's premier conference devoted to sustaining supplies through water reuse and desalination.  
[www.watereuse.org/symposium28](http://www.watereuse.org/symposium28)

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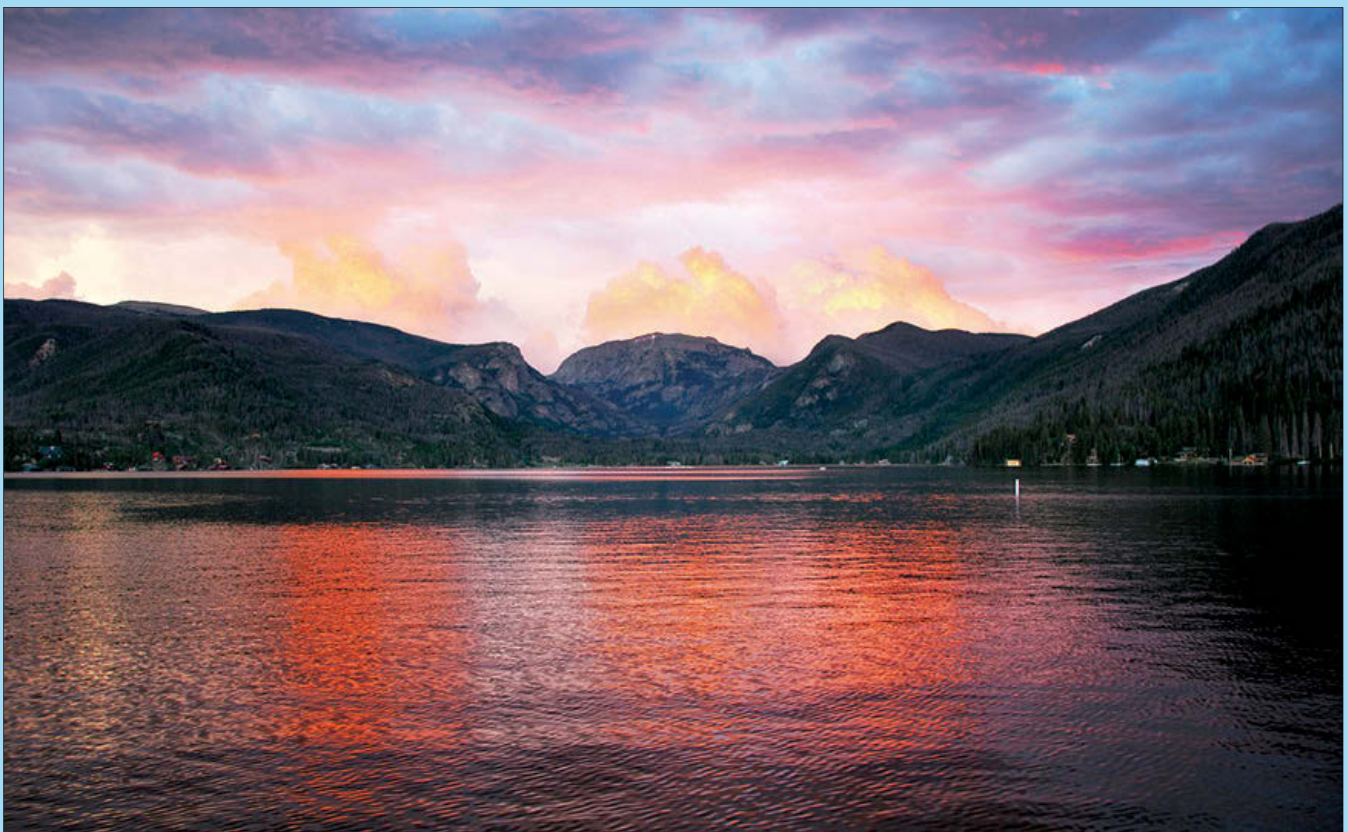
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*Grand Lake, which contributes to the Colorado River.*

Photo by J. Rossol