

The Western Water Assessment

**Annual RISA Report
Reporting Period: January-December 2006**



Prepared April 2007

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WWA Mission: *The mission of the Western Water Assessment is to identify and characterize regional vulnerabilities to climate variability and change, and to develop information, products and processes to assist water-resource decision-makers throughout the Intermountain West.*

I. Focus Areas

A list of ongoing projects will be supplied as an appendix to this memo. In very general terms, here are our current focus areas:

Geographic: Colorado, Wyoming, Utah, and the Rio Grande drainage in New Mexico, with a special focus on the Front Range of Colorado and the entire Colorado River.

Temporal: Historically, our efforts have been oriented towards paleoclimate and seasonal forecasting because our stakeholders demanded this information. In the past six months, however, most requests have been for climate change related information. We anticipate the demand for this information will only grow over time but we will continue to service seasonal and paleoclimate needs.

Sectoral: We continue to focus on water from both supply side and demand side perspectives. Although we occasionally work in other sectors, e.g., agriculture and tourism, water continues to be the sector with the greatest traction for engaging the broadest range of stakeholders given limited resources.

Outreach and Educational Focus: In the last year we've substantially stepped up these efforts and have held or sponsored approximately 10 workshops, published the Intermountain Climate Summary on a regular basis, provided more than 20 invited talks at various high profile events, and have begun to utilize our website as a regional climate information clearinghouse. We anticipate this directed effort will continue.

II. Main Stakeholders & Partners

(See appendix for a list of individual contacts)

State of Colorado and Colorado Municipal Agencies

These include state agencies such as the Colorado State Engineer in the Department of Natural Resources, the Colorado Water Conservation Board and its Water Availability Task Force; regional organizations including the Northern Colorado Water Conservancy District, Colorado River Water Conservation District; and municipal entities including the cities of Denver, Aurora, Colorado Springs, and Boulder.

Colorado River Basin Federal, State and Municipal Agencies

Our new Colorado River focus has brought us contact with a relatively new set of stakeholders. These include California Department of Water Resources, Arizona Department of Water Resources, Wyoming State Engineer, New Mexico State Engineer, Southern Nevada Water Authority, and Upper Colorado River Commission. The Lower Colorado Bureau of Reclamation is a critical stakeholder.

National Weather Service including the Colorado River Basin Forecast Center (CBRFC)

We consider NWS an important stakeholder and partner. This includes Regional Climate Focal Points, Climate Services Division, Climate Prediction Center, Local WFOs and the Colorado Basin River Forecast Center.

Natural Resource Conservation Service

The NRCS is an important partner and information source for the Intermountain West Climate Summary. We are in constant communication with the NRCS for updated water and climate information useful in WWA research.

Colorado Judicial System

Colorado Supreme Court Justice Hobbs is a noteworthy stakeholder.

Other

The Western Governors' Association is a critical stakeholder as is The American Association of State Climatologists.

III. Research Highlights

(note: WWA Funded individuals noted by “*”, NOAA core individuals by “+”)

1. Outreach, Education, and Directed Climate Products

Project Title: The Intermountain West Climate Summary

PI’s: Andrea Ray+, NOAA, Jessica Lowrey*, CIRES, Eileen McKim*, CIRES, Christina Alvord*, CIRES, Barb Deluysi, CIRES

The Intermountain West Climate Summary (ICS) provides the latest climate information in a simple compact document aimed at managers, planners, and policy makers with water-related interests. By improving awareness and understanding about forecasts as well as climate phenomenon, the climate summary helps WWA facilitate a dialog among potential users, researchers and operational providers of climate information with the ultimate goal of providing enhanced climate services. The ICS is typically released about 8 times per year and is posted on the WWA website.

http://wwa.colorado.edu/products/forecasts_and_outlooks/intermountain_west_climate_summary/

ICS e-mail: wwasummary@wwa.colorado.edu

Project Title: Web Development

PI’s: Chris Goemans*, CIRES, Christina Alvord*, CIRES, Brad Udall*, CIRES

Homepage & General Development:

In the past year, WWA has focused on web development as a primary research and outreach tool geared towards user groups. The homepage was redesigned with special focus on daily updates to the “Water and Climate in the News,” “Upcoming Events,” and “Past WWA Activities” boxes. In the coming year, WWA will continue to revamp the website, including restructuring of WWA research themes, and adding content. Serving as an information-clearing house is another priority in 2007, as we will develop a searchable database of publications, presentations, posters, and maps organized by WWA research themes including, but not limited to: paleoclimate, climate variability and change, water use and demand, drought management, forecasting, and hydrological processes. Researchers Chris Goemans, CIRES, Christina Alvord, CIRES, Brad Udall, CIRES.

Current Research Webpages: We have currently revamped the Current Research section on the WWA webpage. Broken down into three distinct categories, Scientific Assessments, Water and Climate Products, and Outreach to User Groups, the goal is to cater WWA research to potential user groups including water managers and policy makers, climate researchers, attorneys, and interested citizens. In the coming year, we will continue to add content to these webpages.

URL: http://wwa.colorado.edu/themes/current_research/

Colorado River Resources website: (Climate, Management, Law and Policy): Based on a google web analysis, the Colorado River resource webpages constitute nearly half of WWA web visitors, and thus is an important component to the website. The goal is to enhance and update existing site on matters of interest to Colorado River water managers. In addition, we will add discussion of useful existing climate products and new climate product needs by water managers. Researchers Roger Pulwarty, NOAA, Doug Kenney, NRLC, Andrea Ray+, NOAA, Brad Udall, CIRES, Jessica Lowrey, CIRES, Christina Alvord, CIRES

URL: http://wwa.colorado.edu/resources/colorado_river/

Colorado River Streamflow - A Paleo Perspective website. This site will provide information about long-term variations in streamflow for the Colorado River basin, including the 2006 Woodhouse, Gray, Meko tree-ring reconstruction of flow at the Lees Ferry gage. Researchers Connie Woodhouse, University of AZ, Jeff Lukas, CIRES. David Meko (UA-CLIMAS).

URL: <http://wwa.colorado.edu/resources/paleo/>

TreeFlow: Streamflow Reconstructions for the West website. This redesigned website will be an expansion of an existing website on tree-ring streamflow reconstructions for Colorado, and encompasses reconstructions across the western U.S. The website allows water managers to access and utilize streamflow sequences much longer than the historical gage record to better plan for climate variability and change. Jointly funded by the NCDC Paleoclimatology Branch. Researchers Connie Woodhouse, University of AZ, Jeff Lukas, CIRES

URL: <http://www.ncdc.noaa.gov/paleo/streamflow/>

Project Title: Reorganization of U.S. Climate Data in New Climate Divisions

PI's: Klaus Wolter, CIRES

Overview

Traditional Climate Divisions cover the conterminous United States rather unevenly. A map of the 344 NCDC climate divisions currently in use (top) features up to TEN divisions per state. Colorado with only five divisions is a rather egregious example of a large state with complex topography and regional climates that are not represented well, while its neighbor to the north has 10 divisions despite fewer climate stations.

New Climate Divisions are being developed based on multivariate statistical analyses of seasonal correlation matrices for temperature and precipitation among all U.S. stations. Results from two methods are compared against each other, and used to create new climate divisions from the intersection of both analyses. An early version of such climate regions has been used to make improved seasonal precipitation forecasts

(<http://www.cdc.noaa.gov/people/klaus.wolter/SWcasts/>). Follow-up products could include new "drought divisions" that focus on the typical spatial and temporal scales of U.S. drought patterns.

URL: <http://www.cdc.noaa.gov/people/klaus.wolter/ClimateDivisions/>

2. Municipal Water Management along the Front Range, CO

Project Title: Front Range Water Demand

PI's: Douglas Kenney*, NRLC, Bobbie Klein*, CIRES, Andrea Ray+, NOAA, Chris Goemans*, CIRES, and Jessica Lowrey*, CIRES

Overview

During the past year, WWA has made residential water demand a major focus area, working in collaboration with Aurora Water (the municipal water utility serving Aurora, CO). While the influence of weather and climate on residential water demand is an important issue covered in this research, our primary “climate interest” in this project is not how weather/climate influences demand, but rather, how can we improve the ability of western water managers to use demand management as an adaptation mechanism for systems stressed by climate variability and change. Demand management is quite likely the most economically and politically viable of all adaptation options, but it is also among the most poorly understood. Opportunities/constraints for manipulating outdoor water use (primarily for lawn watering) is the primary concern, as this comprises the bulk of summertime residential water use in many western/southwestern cities.

Phase 1 of research is currently wrapping up. To date, this research has involved compiling a research database of household water-use statistics, and conducting an analysis of that data to better evaluate the efficacy of various demand management tools (e.g., pricing policies, restrictions of water-use, technology rebate programs) employed by the City of Aurora over the past 5 years, a turbulent period featuring severe drought conditions and a variety of management interventions. (For information about Phase II, see Section VII, Other Projects)

Project Title: Probabilistic Seasonal Forecasting System for Water Utilities Using NOAA Products for Water Supply Forecasting

PI's: Balaji Rajagopalan*, CIRES, Brad Udall*, CIRES, Klaus Wolter*, CIRES, Robert S. Webb+, NOAA

Overview

NOAA's National Weather Service, through four River Forecast Centers (RFCs) and in cooperation with the Natural Resources Conservation Service (NRCS), prepares seasonal water supply volume forecasts for selected sites in Colorado. These forecasts are typically issued on the first of each month, from January through June and consist of estimates of the total volume of water that could occur at a specific location throughout the forecast time period, most commonly running from April through July.

While these volume forecasts are widely relied upon to give early warning of potential flooding or drought, there are three primary barriers to use of volume forecasts in water supply operational planning: The current forecasts are not for relevant decision variables (e.g. end-of-year reservoir contents); there is a mismatch between the temporal and spatial scale of the forecasts and the planning needs of the water supply organizations; and water management organizations are often not aware of the advancements in climate science and that cost-effective techniques have become available that would allow the use

of available climate forecast products to be used to derive operational forecast products. This project aims to develop a pilot application that will use NOAA/NRCS products to produce probabilistic forecasts of relevant decision variables for four participating water utilities, City of Aurora, Boulder, Colorado Springs, and Denver. This project is jointly funded by these four utilities and NOAA Western Water Assessment Program.

Affiliate Cities

City of Aurora: Alfredo Rodriguez, Rick Marsicek

City of Boulder: Carol Ellinghouse

Colorado Springs Utilities: Brett Gracely, Danielle Kitover, Abby Ortega

Denver Water: Bob Steger, Marc Wagge

Hydrosphere Resource Consultants: Benjamin L. Harding*, Subhrendu Gangopadhyay*

3. Colorado River Basin Research

Project Title: Integration of WWA Activities with the “Climate and Management of the Colorado River” project, funded separately by NOAA under the Human Dimensions (SARP or “Sectors”) initiative.

PI’s: Douglas Kenney* NRLC, Brad Udall*, CIRES, Andrea Ray+, NOAA, Roger Pulwarty+, NOAA, Connie Woodhouse*, University of AZ, Jeff Lucas*, CIRES, Ben Harding*, Hydrosphere Consultants, Chris Goemans*, CIRES.

Overview:

WWA activities regarding the Colorado River are largely motivated by ongoing drought in the Colorado River Basin, which has significantly depleted storage in Lakes Powell and Mead, and which has raised difficult questions regarding how the region may be impacted by, and may respond to, forthcoming water shortages on a scale never before experienced in this basin. These were themes explored in the early 1990s in an ambitious research project called the *Severe Sustained Drought in the Southwestern United States* (SSD) study (hereafter the "SSD study"). At the time of publication, the tree-ring hydrology used in that study was widely considered to describe an unrealistically harsh scenario, and the study results were largely ignored. However, given recent events, interest in the SSD is now at unprecedented levels. In this project, the general themes and conclusions of the SSD study are being revisited, in part to better understand how climate variability and change is changing water supply vulnerability in the region, and in part to further inform and contribute to efforts (by WWA and others) to integrate climate scenarios into long-term thinking about management of the Colorado River.

Given the obvious synergies between the SSD review and WWA Colorado River projects and personnel, there are several synergies to be accomplished by project integration. Specifically, this collaboration allows an expansion of products most directly associated with the core Human Dimensions study to expand from a single professional paper (in preparation) explicitly revisiting the SSD study to include additional articles on river yield/reliability (led by Udall) and documents/workshops designed to bring greater sophistication in the use of climate information to planning and management efforts (led

primarily by Udall, Harding and Ray), including the ongoing federal EIS process examining modified reservoir operations and shortage sharing rules.

Project Title: Paleo Climate Research & Workshops

PI's: Jeff Lukas*, CIRES, Connie Woodhouse*, University of Arizona, Subhrendu Gangopadhyay*, Hydrosphere Resource Consultants, Ben Harding*, Hydrosphere Resource Consultants, Balaji Rajagopalan*, CIRES, Robert Webb+, NOAA.

Non-parametric streamflow reconstructions

Tree-ring reconstructions of streamflow have invariably used parametric statistical techniques, usually multiple linear regression, to generate the statistical model relating the gaged streamflow record to the tree-ring data. There have been numerous refinements of these techniques, but the limitations inherent to parametric statistics (e.g., assumptions about underlying distributions of the data) and regression remain. Non-parametric techniques have been successfully used in other areas of hydrologic modeling, but have not yet been applied to tree-ring reconstructions. This new project, funded by WWA and the US Bureau of Reclamation, will develop and prove a methodology for using a non-parametric *k*-nearest-neighbor technique to generate a streamflow reconstruction, for the Colorado River at Lees Ferry, that is driven more directly by the tree-ring data. This effort will be led by Subhrendu Gangopadhyay and Ben Harding of Hydrosphere Resource Consultants, with assistance from Jeff Lukas, Connie Woodhouse, Balaji Rajagopalan (CIRES), and Robert Webb (NOAA).

New reconstructions for the Upper Colorado River Basin

Woodhouse and Lukas have developed a network of over 60 new tree-ring datasets in the Upper Colorado River Basin (UCRB) and the surrounding region since 2001. These were used as the basis for a new 462-year reconstruction of annual streamflow for the Colorado River at Lees Ferry (Woodhouse et al. 2006), arguably the most important single stream gage in the West. The new reconstruction has a long-term mean that is significantly lower than the gaged mean and shows a much greater range of drought events than seen in the 100-year gaged record, including a very severe four-year drought in the late 1840s. Woodhouse et al. also generated flow reconstructions for nine other key UCRB gages. The new reconstructions are being used by the US Bureau of Reclamation to support the development of shortage criteria and coordinated reservoir operations in the Colorado River.

Paleo Climate Workshops

Woodhouse and Lukas have held three technical workshops in Colorado and Arizona since spring 2006, providing over 30 water managers and other data users with information about how the tree-ring data and reconstructions of streamflow are generated, the characteristics of these data, and how water entities are successfully incorporating the data into modeling and planning. Workshops will be held in several locations in 2007.

Technical Workshops on Tree-Ring Reconstructions of Streamflow

- April 26, 2006, Alamosa, CO
- May 8, 2006, Boulder, CO
- November 1, 2006, Tucson, AZ

Project Title: Dust on Snow Research

PI's: Tom Painter*, NSIDC, A. P. Barrett*, NSIDC, C. Landry, J. Neff, CU

Overview

Each winter and spring, the Colorado Plateau emits dust storms of magnitudes great enough to cover the alpine snow-covered ranges of Colorado with dust layers that significantly decrease snow albedo and accentuate the evolution of the snowpack. This study will investigate the frequency and magnitude of dust deposition events, their temporal impact on snow albedo, and the relative contributions of global, regional, and local impurity sources. This work will model the basin scale impact of dust in snow through the albedo effect. We will model snowmelt on a 100 m grid in the Senator Beck basin in the San Juan Mountains, Colorado. With the detailed radiation measurements that we make at two towers in the basin, we can infer the range of radiative forcings imparted by dust in the snow surface layers and produce ensembles of dust-corrected radiation fields (distributed by remotely sensed retrievals of snow albedo) to drive snowmelt through the distributed snow model. We will estimate the impact of dust radiative forcing in snow on the timing and magnitude of peak runoff, and the shape of the basin hydrograph with implications for improving operational runoff forecasting. Given the dramatic impact that we have observed, we hypothesize that the snowmelt hydrographs in these regions are significantly perturbed.

Project Title: Adaptive Management in the Grand Canyon Region

PI's: Roger Pulwarty+, NOAA, Shaleen Jain, U.Me, Jon Eischeid*, CIRES

Diagnosis and Impacts of Warm Season Storms, Floods and Sediment Inputs into the Middle Colorado River: Applications to Decision Making and Adaptive Management in the Grand Canyon Region

The planning and decision processes in the Glen Canyon Dam Adaptive Management Program (GCDAMP) strive to balance numerous, often competing, objectives, such as, water supply, hydropower generation, low flow maintenance, maximizing the tributary supplied sediment, endangered species recovery, and flood control. In this context, use of monitored and predictive information on the warm season floods (at point-to-regional scales) has been identified as lead-information that can potentially facilitate improved planning and operations. In this work, we focus on a key concern identified by the GCDAMP, related to the timing and volume of sediment input into the Grand Canyon. Episodic and intraseasonal variations in the Southwest hydroclimatology are investigated to understand the magnitude, timing and spatial scales of warm season floods. Furthermore, the coupled variations of the flood-driven sediment input (magnitude and timing) from Paria and Little Colorado Rivers into the Colorado River are also of interest. The physical processes are mapped alongside the planning and decision processes for

releases from Glen Canyon Dam which are aimed at achieving restoration and maintenance of sandbars and instream ecology.

Project Title: Climate Information Support to Reclamation

PI's: Brad Udall*, CIRES, Terry Fulp, BOR, Levi Brekke, BOR, David Yates, NCAR, Tom Pinchota, UNR, Ben Harding, Hydrosphere Consultants

Overview

In response to the five-year 1999-2004 drought, Reclamation began an Environmental Impact Statement (EIS) in 2005 to determine how to operate Lakes Mead and Powell in a coordinated fashion, and to establish objective criteria for declaring and implementing shortages on the Colorado River. The Western Water Assessment, along with several collaborators including NCAR, is working with Reclamation to provide an ancillary document to the EIS containing a broad overview of past climate change studies, the current state of the climate change science for regional planning, and a set of potential future work items to help narrow the uncertainty on hydrologic projections. We intend to utilize CIG and CLIMAS personnel to review this effort, which will be completed in May, 2007.

Project Title: Native Communities & Climate Change: Legal and Policy Approaches to Protect Tribal Legal Rights

PI's: Mark Squillace, NRLC, Sarah Krakoff, NRLC, Douglas Kenney*, NRLC, Jon Hanna, NRLC, Christina Alvord*, CIRES, Ethan Plaut, NRLC, Scott Gray, NRLC

Overview

The WWA has contributed to this report, prepared primarily by the University of Colorado Law School (Natural Resources Law Center), examining a diversity of climate change impacts on tribes, as well as how tribes might address these issues through legal and policy measures. The study focuses on 4 regional case studies-Alaska, the Pacific Northwest, the Southwest, and Florida-to discuss how the effects of climate change impacts tribal resources, communities and activities differently in each of these areas, as well as legal and policy measures that tribes might employ to protect their legal rights in the absence of federal action. The penultimate draft of the report was released for review through a national database of American Indian Tribes in February 2007. Final publication is anticipated for summer 2007.

IV. List of Stakeholder Collaborations

Including, but not limited to: workshops, newsletters, list serves, media collaborations

Newsletters

Intermountain West Climate Summary: Released about 8 times per year, this publication provides updated climate and water supply information catered to municipal water providers. Researchers Andrea Ray+, NOAA, Jessica Lowrey*, CIRES, Eileen McKim* CIRES, Christina Alvord*, CIRES

Edition archives available at:

http://wwa.colorado.edu/products/forecasts_and_outlooks/intermountain_west_climate_summary/

Selected Workshops, Meetings & Presentations

AGU Meeting: Klaus Wolter gave presentation on his seasonal climate prediction work. Baltimore, MD, May 25, 2006.

American Meteorological Society Policy Briefing. Future Water Policy in the Western US: The Colorado River. September 25, 2006, Washington, DC. Brad Udall.

Annual meeting of the American Association of State Climatologists (AASC): Klaus Wolter, CIRES gave a talk about his development of climate divisions, and also maintained WWA's linkage to this stakeholder group. Rapid City, SD, June 22, 2006.

Aspen "Canary Project" Workshop: WWA team members attended workshop and served as a climate information source for Workshop organizers and affiliates. Aspen, CO, October 5, 2006

Climate Change for Water Resource Managers Workshop: In conjunction with local consulting firm who is working on a NOAA CPO grant to study climate change with a local water provider (Stratus), the WWA will sponsor a workshop on climate change for water managers. Invitees will include Colorado and Wyoming managers. Researchers Brad Udall, CIRES, Jessica Lowrey, CIRES, Andrea Ray, NOAA, Robert S. Webb, NOAA, Nolan Doesken, CSU. Camp George West, Golden, CO, November 17, 2006.

Climate Change and Variability in the San Juan Mountains: WWA co-sponsored a workshop on purpose of the conference was to facilitate information-sharing and interaction between scientists and local stakeholders regarding the implications and potential impacts of climate variability and change in the San Juan Mountain region. In association with CLIMAS. Fort Lewis College, Durango, CO, October 11-13, 2006.
URL: <http://www.mountainstudies.org/>

Climate Diagnostics and Prediction Workshop (CDPW): Klaus Wolter gave poster on seasonal 'forecast guidance' and its real-world skill. Boulder, CO, October 26, 2006.

Climate and Tourism Workshop: Identifying links between climate variability and change and tourism industries on the Colorado Plateau. Workshop participants

represented the various tourist sectors including golf, ski, and rafting, as well climate experts, journalists, water managers, and local NGO's. Researchers Roger Pulwarty, NOAA, Christina Alvord, CIRES, Brad Udall, CIRES, Patrick Long, University of Colorado, Leeds School of Business. National Center for Atmospheric Research, Mesa Laboratories, January 23-24, 2007.

URL: <http://wwa.colorado.edu/outreach/climatetourworkshop.html>

Climate Prediction & Application Workshop (CPAW): Klaus Wolter, CIRES, gave presentation/update on new climate divisions that will eventually be adopted by National Climate Data Center (NCDC) for climate monitoring purposes. Tucson, Arizona, March 23, 2006

NCDC: Follow-up presentation at NCDC, Asheville, North Carolina, May 23, 2006.

CPC (Climate Prediction Center): Klaus Wolter, CIRES, gave presentation on the use of climate divisions that still forms the basis for some of their statistical predictions. The new climate divisions are scheduled to be finished in 2007. Washington D.C., May 26, 2006.

Climate Support Collaboration with Bureau of Reclamation: In response to the five-year 1999-2004 drought, Reclamation began an Environmental Impact Statement (EIS) in 2005 to determine how to operate Lakes Mead and Powell in a coordinated fashion, and to establish objective criteria for declaring and implementing shortages on the Colorado River. WWA sponsored a large kick-off meeting with approximately 30 individuals. Researchers Brad Udall, CIRES, Terry Fulp, BOR, Levi Brekke, BOR, David Yates, NCAR, Tom Pinchota, UNR, Ben Harding, Hydrosphere. National Center for Atmospheric Research, Boulder, CO, November 7, 2006.

Integration of WWA Activities with the “Climate and Management of the Colorado River” project, funded separately by NOAA under the Human Dimensions (SARP or “Sectors”) initiative. This project entails a variety of interactions between WWA personnel and Colorado River stakeholder at relevant meetings (e.g., the annual meeting of the Colorado River Water Users Association); more focused workshops and collaborations—e.g., the paleo reconstruction workshops for Colorado water managers (May 8-9, May 17, 2006)—are more directly associated with other elements of the WWA Colorado River agenda, and are thus summarized elsewhere. Researchers Douglas Kenney, NRLC, Brad Udall, CIRES, Andrea Ray, NOAA, Roger Pulwarty, NOAA, Connie Woodhouse, University of Arizona, Jeff Lucas, CIRES. Ben Harding, Chris Goemans.

Presentations

- *“Critical challenges in incorporating climate into management of the Colorado River.”* A.J. Ray and D. Kenney. AMS Second Symposium on Policy and Socio-economic Research (January 18, 2007).
- *“Tree Rings and Past Flows on the Colorado River.”* C.A. Woodhouse. Colorado River Roundtable meeting, Glenwood Springs, CO (August 2006).

Colorado River Roundtable meeting, presentation: “Tree Rings and Past Flows on the Colorado River.” Connie Woodhouse, University of Arizona, Glenwood Springs, CO, August 2006.

Colorado Water Conservation Board (CWCB) Water Availability Task Force (WATF) Collaboration and Assistance: Provide technical support for Governor’s drought task force as needed. Researchers Klaus Wolter, CIRES, Jessica Lowrey, CIRES, Andrea Ray. NOAA, Colorado DOW Office, Denver, CO, monthly meetings.
URL: <http://www.cwcb.state.co.us/Conservation/Drought/waterAvailability.htm>

Council of State Governments – West. Past, Present and Future Climate of the Colorado River. August 10, 2006. Breckinridge, CO. Brad Udall

Front Range Residential Water Demand:

All work to date has been done with the active participation of Aurora Water. Our work is also loosely connected to the work of the Colorado WaterWise Council, which is a consortium of water conservation and demand management specialists representing a variety of Colorado water utilities. Researchers Douglas Kenney, NRLC, Bobbie Klein, CIRES, Andrea Ray, NOAA, Chris Goemans, CIRES, and Jessica Lowrey, CIRES

Presentations.

- *Managing Residential Water Demand: Lessons from Aurora.* Doug Kenney and Chris Goemans. Held at the Center for Science and Technology Policy Research, University of Colorado (March 8, 2002), and attended by water utility representatives from several Colorado cities, including Aurora, Denver, Boulder, Colorado Springs, Westminster, and the Northern Colorado Water Conservancy District.
- *Behavioral and Econometric Lessons from Urban Water Demand under Extreme Drought: Focus on Aurora Colorado.* Chris Goemans. Presented as part of the Department of Agricultural and Resource Economics & Department of Economics U.S. Forest Service Rocky Mountain Research Station Spring 2007 Seminar Series (February 16, 2007).
- *Municipal Water Planning: Identifying Which Households Respond to Demand Management Programs and By How Much.* Colorado’s Future Water Conference, held in Copper Mountain, CO (October 5, 2006). (This was a major water conference attended by approximately 100 key water managers and policy-makers from across the state.)
- The “Water Demand and Conservation” pages of the Western Water Assessment: http://wwa.colorado.edu/resources/water_demand_and_conservation/ (Most of the above-mentioned papers and presentations are currently posted, and are among the most visited of all WWA pages.)

High Country Citizens’ Alliance. The Changing Climate of Climate Change. Sept. 28, 2006. Crested Butte, CO. Brad Udall.

Joint Inter American Institute for Global Change Research and Advanced Study Program Colloquium, Policy Planning and Decision Making Involving Climate Change

and Variability, "The Science of Climate Variability: Paleoclimate." National Center for Atmospheric Research, Boulder, CO, Sept. 11-22, 2006.

National Association of Clean Water Agencies. Future Water Quality Challenges and the Role of Reuse. July 20, 2006. Seattle, WA. Brad Udall.

National Wildlife Federation Tribal Lands Conference. Climate Threats to the Colorado River. December 5, 2006. Yuma, AZ. Brad Udall.

National Seasonal Assessment Workshop (NSAW) for Wildfire Potential in the Western States and Alaska: Klaus Wolter gave presentation on outlook for both the interior southwestern U.S., as well as for all of North America (representatives from Canada and Mexico were present for the first time at this meeting). Researchers Klaus Wolter, CIRES, Robert Webb, NOAA, Boulder, CO, April 4, 2006. (In association with CLIMAS and Gregg Garfin.)

NIDIS Planning Meeting: presented "WWA Activities" poster. Klaus Wolter, CIRES, Christina Alvord, CIRES, Longmont, CO, September 21-22, 2006.

Probabilistic Seasonal Forecasting System for Water Utilities Using NOAA Products for Water Supply Forecasting Kickoff Meeting: NOAA's National Weather Service, through four River Forecast Centers (RFCs) and in cooperation with the Natural Resources Conservation Service (NRCS), prepares seasonal water supply volume forecasts for selected sites in Colorado. October, 2006.

Affiliate Cities:

City of Aurora: Alfredo Rodriguez, Rick Marsicek

City of Boulder: Carol Ellinghouse

Colorado Springs Utilities: Brett Gracely, Danielle Kitover, Abby Ortega

Denver Water: Bob Steger, Marc Wagge

Hydrosphere Resource Consultants: Benjamin L. Harding, Subhrendu Gangopadhyay

South Platte Forum: Klaus Wolter, CIRES, gave forecast for the upcoming winter season. Longmont, CO, October 26, 2006.

Technical Workshops on Tree-Ring Reconstructions of Streamflow: Woodhouse and Lukas have held three technical workshops in Colorado and Arizona since spring 2006, providing over 30 water managers and other data users with information about how the tree-ring data and reconstructions of streamflow are generated, the characteristics of these data, and how water entities are successfully incorporating the data into modeling and planning

Workshop Dates & Location

- April 26, 2006. Alamosa, CO
- May 8, 2006, Boulder, CO
- November 1, 2006, Tucson, AZ

27th Annual NRLC Summer Conference: Climate Change and the Future of the American West: Exploring the Legal and Policy Dimensions;

WWA assists as a co-sponsor for the CU Law School Workshop on climate change for attorneys and other decision makers. Natural Resource Law Center at the University of Colorado, June 7-9, 2006. Brad Udall presentation.

URL: <http://www.colorado.edu/law/centers/nrlc/summerconference/2006/index.htm>

Upper Colorado River Commission. Climate Change Predictions and Impacts on Colorado River Water Supplies. Dec 13, 2006, Las Vegas, NV. Brad Udall.

US Conference of Mayors Annual Meeting. Climate Change and Water Management. June 2, 2006. Brad Udall (for Chet Koblinsky).

Water, Drought and Wyoming's Climate: WWA co-sponsored an all day workshop hosted by the University of Wyoming and others dedicated to understanding how climate variability and change impacts Wyoming's water resources. University of Wyoming, Laramie, WY, October 5, 2006.

URL: <http://www.uwyo.edu/enr/WyomingWater.asp>

Final Workshop Report:

<http://www.uwyo.edu/enr/WaterClimateConfFall2006/WaterDroughtWyomingClimateWorkshopFinalReportNov2006.pdf>

Western States Water Council: "What's a RISA anyway?". November 15, 2006, Irvine, CA. Brad Udall, Robin Webb, Roger Pulwarty.

Workshop for Resource Managers:, Congreso Internacional de los Servicios Ecosistemicos en los Neotropics. "Paleohydrologic records of streamflow: research to applications." Universidad Austral de Chile, Valdivia, Chile, November 13-17, 2006. Connie Woodhouse.

Media Interviews/Briefings

Paleo Climate Information Source: Connie Woodhouse, University of AZ, Jeff Lukas, CIRES

- Press conference when the NAS Committee report, Colorado River Basin Management: Evaluating and Adjusting to Hydroclimatic Variability, February 21, 2006
- Woodhouse interview on NPR program, "Colorado Matters," on paleo-climate information, streamflow reconstructions on the Colorado River, and demand and management implications, April 2, 2007.
- Information resource for LA Times
- Information resource for Arizona Daily Star

Climate Outlooks and Forecasts: Klaus Wolter, CIRES

- Regular briefings on climate forecasts and outlooks, regional El Niño/La Niña impacts, storm tracking information, and how unusual various (recent) weather patterns have been with local media outlets including The Boulder Daily Camera,

The Denver Post, and Rocky Mountain News, Longmont Times Call, Loveland Reporter Herald, Estes Park Trail Gazette, Evergreen Canyon Carrier, Summit Daily News, Vail Daily, Steamboat Pilot, Montrose Daily Press, etc. (more than half of these contacted at least twice last year). Some of these interviews were prompted by Press Releases / radio interviews through CU (Dirk Martinis their media liaison).

- Interviews with Associated Press (usually the Denver affiliate), Albuquerque Journal, Ski Magazine, Palm Beach Post, Los Angeles Times, pertaining to ENSO (and its impacts, for instance on the Atlantic Hurricane season).
- TV& Radio interviews include Denver Channels 2, 4, and 9, KOAA-TV from Colorado Springs, as well as Fox National News, and three times NPR. Topics ranged from assessment of the recent and expected drought situation in the region, to assessments of the national drought situation, and the threat of climate variability and change to U.S. and European ski resorts.
- U.S. Drought Monitor (together with Gary Bates): repeated comments on drought assessment in Colorado that helped modify weekly USDM maps. This was also in coordination with the Colorado Climate Center, Colorado State Climatologist (Office).
- Monthly conference calls with the Climate Prediction Center (CPC) on monthly and seasonal climate outlooks, which occasionally resulted in their modification of forecasts before public release. These comments focused on the interior southwestern U.S., but often included the rest of the western U.S., including Alaska. In particular, the Drought Outlooks issued by Douglas LeComte (CPC) and published on the USDM web site were often modified to reflect comments.
- Same context: monthly updated SWcasts, which include executive summaries that are sent to regional media and stakeholders (<http://www.cdc.noaa.gov/people/klaus.wolter/SWcasts/>). Some of these mailings prompted media interviews, but some also preempt them.

Climate Change Information Source: Brad Udall

- Information resource for LA Times, Albuquerque Journal, Denver Post, Rocky Mountain News, Boulder Daily Camera, High Country News, National Public Radio.

Colorado River Information Source: Brad Udall

Information resource for above entities.

Listserv

Intermountain West Climate Summary e-mail listserv:

Stakeholders: Municipal and agricultural water resource managers, climate researchers, attorneys, policy makers

Listserv Type: Monthly e-mail releases.

Listserv Amount: 278

V. Affiliations with other NOAA Programs

(Individual contacts in Appendix section)

Climate Prediction Center: <http://www.cpc.noaa.gov/>

Climate Services Division: <http://www.weather.gov/os/csd/index.shtml>

National Weather Service (NWS): <http://www.nws.noaa.gov/>

Cheyenne, WY WFO: <http://www.crh.noaa.gov/cys/>

Salt Lake City, UT WFO: <http://www.wrh.noaa.gov/slc/>

Boulder, CO. WFO: <http://www.crh.noaa.gov/den/>

Colorado River Basin Forecast Center (CBRFC): <http://www.cbrfc.noaa.gov/>

U.S. Drought Assessment:

http://www.cpc.noaa.gov/products/expert_assessment/drought_assessment.shtml

National Integrated Drought Information System (NIDIS):

WGA Report: “Creating a Drought Early Warning System for the 21st Century: The NIDIS,” 2004. URL: <http://www.westgov.org/wga/publicat/nidis.pdf>

Senate NIDIS Bill, May 2006:

<http://www.westgov.org/wga/initiatives/drought/S2751.pdf>

House NIDIS Bill, June 2006:

<http://www.westgov.org/wga/initiatives/drought/HR5136.pdf>

National Drought Mitigation Center:

<http://drought.unl.edu/>

VI. Current Cross-RISA Activities

The regional focus of the RISAs has been critical to their success. However, when a climate-related problem exceeds the existing regional boundaries, involves all RISAs, or can easily scale expertise and solutions developed in one region for use in another, the program need to acknowledge and promote these opportunities. The following are thus potential areas for collaborative efforts:

Colorado River: In terms of geographic focus, we believe the Colorado River is a critical area. It is enormously important to the economies of the seven signatory states to the Compact, it has been subject to significant climate variability in the recent past, and the AR4 findings indicate it will experience less precipitation in the future. In addition, the Western RISAs have a wide variety of policy, hydrological and meteorological expertise suitable to the problem solving in the basin and, of course, three RISAs are located in the basin. Future work will revolve around understanding vulnerabilities, coping strategies, and adaptations for future water management. Specifically, we are working in the following areas: (1) continuing research on the future trends in snow and runoff in the basin with CAP, CIG, and CLIMAS; (2) use of paleoclimate data in the basin for planning purposes with CLIMAS and CAP; (3) involvement in a NIDIS pilot project; (4) educational efforts with the large number of stakeholders. Reclamation's Climate Technical Work Group summary, authored in part by WWA, has been sent for review to CAP, CIG and CLIMAS.

National Climate Service Scoping: Congress may hold hearings soon on this topic. The RISAs need to be active in providing a unified vision for this critical need. In the next few years climate change will force congressional and executive level attention on this topic. WWA will play a coordination role.

Climate Summary collaboration: The WWA Intermountain Climate Summary was modeled after the CLIMAS Southwest Climate Outlook. We share articles and expertise and will continue to do so in the future.

Paleoclimatic Reconstructions: WWA, through Connie Woodhouse, is working with CLIMAS on activities in the Rio Grande and the Colorado River.

VII. Appendix Publications

Peer Reviewed (submitted or in preparation):

Goemans, C., A. Strong, D. Kenney, and R. Klein. (in preparation) 2007. *Quantity Uncertainty and the Role of Information in an Increasing Block Rate Structure: Water Smart Readers.*

Goemans, C., D. Kenney, R. Klein. (in preparation) 2007. *Correctly Accounting for the Interaction of Price and Restrictions when Estimating Residential Water Demand.*

Howe, C.W., C. Goemans. *The Simple Analytics of Demand Hardening.* In submission (2007) to the Journal of the American Water Resources Association.

Kenney, D.S., B. Harding, A. Ray, and R. Pulwarty. (in production). *Severe Drought on the Colorado: Moving Beyond the Worst Case Scenario?* For submission to the Journal of the American Water Resources Association, summer 2007.

Kenney, D.S. 2007 (in press). "Hard Times on the Colorado River: A Looming Crisis?" IN: The Politics of Water Scarcity: A Survey, by Julie Trottier and Vincent Mioc (editors). Routledge Publishers.

Kenney, D.S., C. Goemans, R. Klein, J. Lowrey, and K. Reidy. (in production) *Residential Water Demand Management: Lessons from Aurora, Colorado.* In submission (2007) to the Journal of the American Water Resources Association. (This paper provides an overview of the entire Phase 1 of research.)

Pielke, R.A., Sr., K. Wolter, O. Bliss, N. Doesken, and B. McNoldy (2007): *The July 2005 Denver Heat Wave: How Unusual Was It?* National Weather Digest, 31, in press.

Other Publications and Working Papers (Not peer reviewed)

Front Range Water Demand

Kenney, D.S., C. Goemans, R. Klein, J. Lowery, and K. Reidy. *Residential Water Demand Management in Aurora: Learning from the Drought Colorado Water*, February/March 2007, pp. 14-16. (This is a feature article in the primary newsletter of the Colorado water management community.)

Klein, R., Kenney, D.S., J. Lowery, and C. Goemans. *Factors Influencing Residential Water Demand: A Review of the Literature.* 2007. (This is a frequently updated working paper posted on-line as a reference for both water managers and the research community.)

Klein, R., C. Alvord. *Municipal Water Demand and Conservation: Western Water Assessment Studies. Intermountain West Climate Summary*, July 2006

Intermountain West Climate Summary:

2006-2007 Editions including Feature (FA) and Focus Articles (FP):

January 2006

FA: *How to use the climate Forecast Evaluation Tool*, by Melanie Lenart of CLIMAS

FP: *Introduction to NOAA Earth System Research Laboratory*

March 2006

FA: *New and improved NRCS snow and water supply forecast products*, by Tom Pagano of the NRCS National Water and Climate Center.

FP: *The Community Collaborative Rain, Hail, and Snow Network (CoCoRaHS)*, by Eileen McKim of the University of Colorado.

April 2006

FA: *South Platte Regional Assessment Tool (SPRAT)*, by Chris Goemans of WWA.

FP: *Arkansas Basin River Forecasting Center (ABRFC)*, by Keah Schuenemann and Eileen McKim of WWA.

May 2006

FA: *NOAA's National Weather Service Introduces New Local Climate Products*, by Andrea Bair (NOAA/NWS, Western Region Headquarters), Marina Timofeyeva (NWS/Climate Services Div. and UCAR), Jenna Meyers (NOAA/NWS, Western Region Headquarters), and Annette Hollingshead (NWS/Climate Services Div. and RS Information Systems, Inc.)

FP: *National Weather Service Western Region and its Climate Service Activities*, by Keah Schuenemann and Eileen McKim, Western Water Assessment

June 2006

FA: *New Streamflow Reconstructions for the Upper Colorado River Basin: Placing Recent Droughts into a Centuries-Long Context*, by Connie A. Woodhouse (NOAA/National Climatic Data Center), Eileen McKim (CIRES), and Andrea Ray (NOAA/ESRL)

FP: *Advances in Soil Moisture Science: New in situ soil moisture measurements from NRCS*, by Christina Alvord (Western Water Assessment)

July 2006

FA: *Municipal Water Demand and Conservation: Western Water Assessment Studies*, by Bobbie Klein and Christina Alvord, Western Water Assessment

FP: *Update on the 2006 North American Monsoon*, by Eileen McKim, WWA and University of Colorado Dept. of Geography

September 2006

FA: *New spatial information in the National Drought Monitor*, by Kelly C. Smith of National Drought Mitigation Center and Christina Alvord of Western Water Assessment.

November 2006

FA: *A Review of Monthly/Seasonal Climate Variability for 2005-2006: The ENSO Cycle*, by Vern Kousky of NOAA Climate Prediction Center and Andrea Ray of NOAA Earth System Research Lab, and Western Water Assessment

FP: *Climate Workshops in Wyoming and Colorado*, by JJ Shinker of University of Wyoming, Ellen Stein of Mountain Studies Institute, Christina Alvord and Brad Udall of Western Water Assessment

Intermountain West Climate Summary Samples: (Abridged Versions)

December 2006

Article Featured: *A Review of Monthly/Seasonal Climate Variability for 2005-2006: The ENSO Cycle*, by Vern Kousky of NOAA Climate Prediction Center and Andrea Ray of NOAA Earth System Research Lab, and Western Water Assessment

January 2006:

Article Featured: *New Streamflow Reconstructions for the Upper Colorado River Basin: Placing Recent Droughts into a Centuries-Long Context*, by Connie A. Woodhouse (NOAA/National Climatic Data Center), Eileen McKim (CIRES), and Andrea Ray (NOAA/ESRL)

Personnel with Direct Interest in WWA

CIRES/Other CU (Funded directly by WWA)

Brad Udall
Christina Alvord
Chris Goemans
Jess Lowrey
Eileen McKim
Klaus Wolter
Jon Eischeid
Balaji Rajagopalan
Doug Kenney
Bobbie Klein
Edie Zagona
Jeff Lukas

NOAA Personnel (Not funded)

Andrea Ray
Robin Webb
Roger Pulwarty
Marty Hoerling

Official PIs (Not funded)

Koni Steffen

Randy Dole

Unofficial PI (not funded)

Susan Avery

Hydrosphere Resource Consultants (funded)

Ben Harding

Subhrendu Gangopadhyay

Current WWA Projects By Temporal Focus

1. Paleoclimate

- Workshops and Support (web page resources) for Water Managers (Woodhouse, Lukas)
- Non-parametric Paleoclimate Reconstructions (Jointly Funded with Reclamation–Hydrosphere, Lukas, Woodhouse, Balaji)
- Paleo Climate in the San Juans with Mountain Studies Institute (also Fort Lewis College) (Woodhouse, Lukas)
- Paleo Perspective on the Colorado River web site (Woodhouse, Lukas, Meko)

2. Seasonal to Interannual

- Intermountain Climate Summary (Ray, Lowrey, Alvord, McKim)
- WATF Support Water Availability Task Force: Seasonal Forecasts (Wolter)
- Runoff Forecasting for Water Managers (Jointly Funded with Denver, Aurora, CSprings, Boulder)
- Impacts of Dust on Snow (Painter)
- New Climate Divisions (Wolter)
- MEI Enhancement (Wolter)

3. Climate Change

- Colorado River Climate Support for Reclamation (Udall, Others)
- Colorado Temperature Analysis (Wolter, Doesken)
- Impacts of Dust on Snow (Painter) Comment: cross listed above.
- Native Americans and Climate Change (with Natural Resources Law Center, Alvord, Kenney)
- CCSP SAP Support
 - 3.1 Review (Udall)
 - 3.3 Extremes Pulwarty
 - 5.3 Decision Support (Webb, Pulwarty)
- Special Technical Report on Climate Change and Water (Pulwarty)
- IPCC WG2 – Pulwarty
 - Adaptation Practices Chapter
 - Water Chapter
 - .Rocky Mountain IPCC Summary

4. Cross-Scale Activities

- Front Range Water Demand (Kenney, Goemans, Klein, Lowrey)
- Colorado River Severe Sustained Drought Follow-On(OGP HD/SARP Funded, Kenney, Ray)
- South Platte Regional Assessment Tool
- NIDIS Support (w/Pulwarty)
 - Likely Colorado River Pilot Project
- User Needs Assessment for Front Range Water Providers (Ray, Lowrey)
- National Interagency Fire Center Conference Support (Wolter, others)
- Tourism and Climate Conference (Pulwarty, Udall, Long, Alvord)
- Colorado River Adaptive Management (Pulwarty, Jain)
- Various NOAA Committees served by WWA
- Estimating the economic impacts of drought (Wilhite, Pulwarty, Hayes, Howe, Supallam Chermak, Eischeid) This is a SARP and USDA Risk Management Agency project
- Gunnison EIS Streamflows (Rajagopalan, Ray)
- "Climate, Water, and Society in the Intermountain West, " with about 10 articles from across WWA activities. Note that Water Resources Research is an AGU journal. (Lead: Ray, ALL)

4. Outreach and Education

- Front Range Climate Change Workshop
- Speakers' Bureau
- Web Presence
- Intermountain Climate Summary (cross-listed above, too)
- Experimental Seasonal Forecast Guidance and related media outreach (cross-listed above, too)
- ENV5 Class, 5810, Water Resources and Environmental Sustainability

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