Written Testimony of
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Oversight Hearing on the Proposed Fiscal Year 2011 Budget Requests for the Bureau of Reclamation and the Water Resources Division of the United States Geological Survey

Before the Subcommittee on Water and Power
Committee on Natural Resources
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Chairwoman Napolitano, Ranking Member McClintock, and other Members of the Committee, thank you for the opportunity to speak with you today on the proposed 2011 budgets of the Bureau of Reclamation and the Water Resources Division of the United States Geological Survey.

My name is Brad Udall. I am the Director of the Western Water Assessment, one of eleven Regional Integrated Sciences and Assessments (RISA) funded by the NOAA Climate Program Office. My RISA center is a joint effort of the NOAA Earth System Research Laboratory in Boulder, the University of Colorado, Colorado State University, the University of Utah, and soon, Utah State University and the University of Wyoming. The twelve-year-old NOAA RISA program was designed to connect climate science with decision makers. Each center is based at one or more universities and covers multiple states. In all, the RISAs now support more than 25 states and have a collective annual budget of approximately $10m. Since 1998 the RISAs have been on the front line of dealing with requests for regional information on all aspects of climate variability and change including past climates, forecasts for the next year, and increasingly climate change.

The RISA which I direct has created numerous products and services during its existence. During the height of the recent drought we created tree-ring based streamflow reconstructions of critical streams in Colorado, and a new reconstruction of the Colorado River going back over 400 years in order to put the 2000s drought in a longer term context[1]. We created a website to provide access to this invaluable paleoclimate data[2]. We regularly provide seasonal forecasts to water managers in the Rocky Mountain West using the best available science[3]. For Colorado's Water Conservation Board, we published *Climate Change in Colorado: A Synthesis to Support Water Resources Management and Adaptation*[4]. We have held numerous workshops and have given hundreds of talks to the public and stakeholders on climate science. Eight times a year we publish the *Intermountain West Climate Summary* for water managers, a compilation from

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[1] Woodhouse, C. A., S. T. Gray, and D. M. Meko (2006), Updated streamflow reconstructions for the Upper Colorado River Basin, Water Resour. Res., 42, W05415, doi:10.1029/2005WR004455.
[2] http://treeflow.info/
[3] http://www.esrl.noaa.gov/psd/people/klaus.wolter/SWcasts/
[4] http://cwcb.state.co.us/Home/ClimateChange/ClimateChangeInColoradoReport/

numerous data sources into a one-stop document[5]. We helped Reclamation create a Climate Technical Work Group for the 2007 Environmental Impact Statement (EIS) for Shortage Sharing and Coordinated Operations on the Colorado River and participated in the creation of Appendix U in the EIS which provided a review of the science and methods for utilizing climate change information in Reclamation's future Colorado River studies[6]. We have published numerous papers on topics of interest to water managers.

Through our work, we have established a broad group of stakeholders in the West. These stakeholders are in part represented by our advisory board. This board is comprised of a high level NOAA scientist, a National Integrated Drought Information System (NIDIS) representative from the USGS, a DOE scientist from the National Renewable Energy Laboratory, the Deputy Regional Director of Reclamation's Lower Colorado Region, the Director of Reclamation's Research and Development Program, the Hydrologist in Charge of NOAA's Colorado Basin River Forecast Center, the Chairman of the Board of Directors of the Metropolitan Water District of Southern California, the General Manager of the Southern Nevada Water Authority, key planning officials from Denver Water Department, the head of the Colorado Water Conservation Board, Trout Unlimited, the Nature Conservancy, and the General Manager of the West Slope based Colorado River Water Conservation District. We pride ourselves on creating a very broad network of important stakeholders in the West.

The RISAs have also provided input into important national and international efforts. RISA researchers have participated in numerous IPCC and U.S. Global Change Research Program (USGCRP) products. RISAs have provided NOAA with guidance documents on what services a National Climate Service should provide[7], as well as a document describing our long-term vision for the RISA program[8]. These efforts make us even more valuable to our local stakeholders because we can provide them with a big-picture perspective of national and global climate science efforts.

It is gratifying to be here today for two reasons, one professional and one personal. On a professional level it is an honor to testify in front of one of the critical congressional committees which oversees federal efforts in the area to which I devote my life. And on a personal note, it is an honor to testify in the hearing room named for my father, the very room where he often presided, and the room where his portrait looms large.

Reclamation and the USGS are two of the most important federal agencies with respect to water. Reclamation's role in water issues in the West needs little explanation -- simply put, it is the most important federal player in western water issues. And the Water Resources Division of the USGS provides critical services to other DOI agencies as well as the nation with respect to water research and water data for management of drinking water, irrigation supplies and species habitat. The financial health, overall direction, and leadership of these two agencies is critical if

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[5] http://wwa.colorado.edu/IWCS/index.html

[6] Appendix U: Review of Science and Methods for Incorporating Climate Change Information into Bureau of Reclamation's Colorado River Basin Planning Studies. Available at: http://www.usbr.gov/lc/region/programs/strategies/FEIS/index.html

[7] http://wwa.colorado.edu/about_us/docs/RISA_NCS_May09_finalV3b.pdf

[8] http://wwa.colorado.edu/about_us/docs/RISA_Vision2020_CF_july2009.pdf

we are to provide the nation with the tools needed to prepare for the water and climate stresses of the 21st century.

Secretary Salazar's Climate Change Order 3289[9] represents a bold and welcome initiative to deal with the threat of climate change. The creation of Interior's Climate Science Centers and Landscape Conservation Cooperatives will provide needed science to support management decisions. The SECURE Water Act[10] also provides a strong basis for climate change adaptation by DOI, especially Reclamation. With cooperation and collaboration with other federal efforts, including that of the RISAs, I believe these authorities will provide DOI with the necessary tools to manage the impacts of climate change.

Today I would like to discuss five critical issues that directly relate to Reclamation and USGS budgets and activities. The first issue is a brief discussion of the close relationship between climate change and water resources. The second issue is ensuring that we provide the nation with the best basic science research and data for decision making related to water. The third issue is ensuring that we have a strong understanding of the impacts of climate variability and change on our water resources including our infrastructure and ecosystems. The fourth issue is the need to have independent review of all science products and independent, innovative research. The fifth and final issue is the need for strong cooperation and collaboration among the many federal and regional entities working on climate and water issues.

The Climate Change – Water Connection

Water is critical resource in the West and increasingly, the entire nation. I recently authored the water sector chapter of the 2009 U.S. Global Change Research Program document entitled *Global Climate Change Impacts in the United States*[11]. The thirty authors of this document decided to place the water sector chapter at the front of the document, ahead of all other sectors, because of its importance to the nation and its direct connection to climate change. Substantial changes to the water cycle are expected as the planet warms because the movement of water in the atmosphere and oceans is one of the primary mechanisms for the redistribution of heat around the world.

According to the report, *"The impacts of climate change include too little water in some places, too much water in other places, and degraded water quality. Some locations are expected to be subject to all of these conditions during different times of the year. Water cycle changes are expected to continue and to adversely affect energy production and use, human health, transportation, agriculture, and ecosystems."*

The report has ten key findings, of which the fourth is: *"Climate change will stress water resources. Water is an issue in every region, but the nature of the potential impacts varies. Drought, related to reduced precipitation, increased evaporation, and increased water loss*

[9] http://www.fws.gov/home/climatechange/pdf/SecOrder3289b.pdf

[10] This act requires the DOI Secretary assess risks to water in each Reclamation basin from changes in snowpack, runoff timing and quality, groundwater recharge, and changes in demand and evaporation. The Secretary is also charged with assessing impacts to hydropower, recreation, fish, ESA issues, water quality, ecological resiliency, and flood control. The act mentions RISAs by name, and requires that the RISAs be consulted on the best available science on presently observed and projected impacts of climate change.

[11] http://www.globalchange.gov/publications/reports/scientific-assessments/us-impacts

from plants, is an important issue in many regions, especially in the West. Floods and water quality problems are likely to be amplified by climate change in most regions. Declines in mountain snowpack are important in the West and Alaska where snowpack provides vital natural water storage."

We now know, and have known for some time, that water will be the delivery mechanism for many of the most important impacts of climate change. We are already seeing changes in the water cycle, which are consistent with the warming observed over the past several decades. These include changes in precipitation patterns and intensity, changes in the incidence of drought, widespread melting of snow and ice, increasing atmospheric water vapor, increasing evaporation, increasing water temperatures, reductions in lake and river ice, and changes in soil moisture and runoff.

Quality Data and Science Research

Climate science has four key domains to support decision makers: data and data analysis, basic climate science, paleoclimate studies, and climate modeling. All are important and the best decisions are made when results from all four areas provide inputs into the decision-making process.

Basic data is the fundamental building block of all science. Simply put, no data means no science and bad data means bad science. Effective management also requires good data. All data – National Weather Service data, USGS streamflow data, and National Resource Conservation Service snow and soil moisture data among many others -- should be covered by a consistent national plan and be provided adequate funding. Data collection is unfortunately the first thing that gets cut in time of shortfall. Meta-data, that is data about data, is especially critical ancillary data because it lets scientists cull bad data from good.

Interior's proposed Global Change Effects Network will unify all DOI data and is a welcome addition to simplify data retrieval and analysis. Unfortunately, it appears that DOIs streamflow data collection program has not been funded at the level necessary to re-establish critical discontinued gages. Water users and scientists have consistently complained about the long-term underfunding of streamflow and reservoir gages.

In my state of Colorado water users have identified over 80 currently inactive gages having twenty or more years of data in the Colorado River Basin alone. These gages would cost approximately $1.5m to reactivate and roughly the same amount to operate annually. Of the over 100 reservoirs in the Colorado River basin, roughly half are not equipped with automated reporting and require tedious phone work to obtain data. To equip these reservoirs with automated equipment would cost approximately $800k with annual costs of roughly $300k. Other parts of the West suffer from similar gaging and data problems. The USGS and Reclamation in consultation with data suppliers and users should systematically evaluate the value of restarting discontinued gages and automating existing manual gages.

Basic science on how the earth and atmosphere operate is also critical. For example, there are now important studies which investigate and explain the mechanisms by which wet areas are expected to get wetter and dry areas drier. Scientific studies which explain how and why basic

climate processes operate can provide decision makers with additional confidence in other scientific results including modeling.

Paleoclimate data serves to put our current climate into a long term context. Tree-ring reconstructions of past streamflow can provide another input for decision making. Frequently paleoclimate studies carry more weight with stakeholders because these studies are perceived to be more real than climate model results. Recently, novel ways of combining paleoclimate data about past drought patterns with current gage flows have created more realistic synthetic streamflow traces necessary for various forms of vulnerability modeling.

Finally, computer models provide valuable insights into the climate system and provide a way to experiment with the earth under different future conditions. Regional models of all sorts are critical. Much of the regional response to climate change needs to revolve around regionally specific climate modeling including various forms of downscaling. Models, however, are not crystal balls and must not be oversold. Nevertheless, they can be extremely valuable when combined with other science.

All forms of science, supported by data collection, are critical for effective decision making and need adequate funding. It appears that Reclamation, through its Science and Technology program, is proposing to spend $4m on science research and support of the new Climate Science Centers. It is difficult to discern how the USGS efforts break into the above categories but $8m is apparently dedicated to the establishment of two Climate Science Centers. Additional funding is needed in these areas.

Understanding the Impacts of Climate Change and Variability on Water Resources

On a global scale we have a very good understanding of how temperatures will change, and a reasonable understanding of how the water cycle will change as the 21st century progresses, subject in part to knowing our future greenhouse gas emissions trajectory. Unfortunately, at the regional level the picture is less clear. While we have a strong understanding of temperature changes, changes in precipitation remain elusive and await better science. And because our basic science is limited, we still don't understand how these changes will impact management of water supplies for human settlements, agriculture, energy, and ecosystems.

Knowledge of these impacts is critical for effective management. We are already seeing significant climate-change related impacts to our water resources from a variety of sources, including some unanticipated and disturbing. Let me mention four areas of concern and active research.

Researchers with the USGS, the Western Water Assessment at the University of Utah and the University of Colorado, and from the RISA at the University of Washington, now believe that the during the 20th century the Colorado River lost up to 5% of its flow due to increased evaporation of snowpack resulting from large amounts of springtime dust. This heat absorbing dust, which sits on top of the snowpack after being transported from the American Southwest to the Colorado mountains, results from human-caused disturbance of soils combined with high wind events. We do not know how these events will evolve in the 21st century, but preliminary indications are for a drier American southwest and more dust, meaning potentially more loss in

flow. The good news is that there are management techniques to minimize such dust emissions[12]. This is an area ripe for additional research on the causes and effects of dust, and the ways to minimize flow losses.

In Colorado and Wyoming, the United States Forest Service recently announced that 3.6m acres (5600 square miles) of lodgepole pine is diseased and dying due to the pine beetle[13]. This event happened very quickly over the last five to eight years and surprised nearly everyone in the region by its extent and rapidity. While this event is not entirely due to climate change, at least a portion of it is related to increasing temperatures. Multi-stressor events, such as this one, are likely to become increasingly common with climate change[14]. We do not know what the loss of these trees mean for winter snowpack retention, spring runoff amounts and timing, water quality and forest fires. Research is much needed on these impacts.

Researchers at the Western Water Assessment, NOAA and Reclamation believe that by 2058 the reservoirs of the Colorado River could be dry up to half of the time if current demand projections are accurate, and if Colorado River flows decline by 20%, as some studies suggest[15]. Even a 10% decline in flows put the risk of empty reservoirs at 30% in any year. This research also suggests that demand management techniques may provide a way to minimize the harm. Studies of this type which investigate the management aspects of water management are rare; very little research has been done on how to re-operate our water systems to minimize future damages.

Finally, researchers from the USGS and from our sister RISA program at Scripps in 2006 released a study published in *Science* showing that since 1985 wildfire seasons have lengthened, fires have lasted longer, and large fires have become more common. These increases are associated with higher spring and summer temperatures and earlier spring snowmelt. The researchers indicate that projections for higher future temperatures and earlier runoff will increase the vulnerability of the West to fires in the 21st century.

These are just four disturbing impacts to our water resources from climate variability and change. Many more novel and unusual impacts are possible. Research on these and other potential impacts is critical and is currently underfunded. Additional work in this realm would be presumably covered by DOI's Climate Science Centers and Landscape Conservation Cooperatives. Current RISA activities in these areas should obviously be fully integrated with DOI's planned activities.

It should be noted that the SECURE Water Act Section 9503 requires climate change impacts studies in all of Reclamation's basins. Reclamation currently has three Basin Study projects

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[12]This paper by Painter et al., is currently under review at the peer-reviewed Proceedings of the National Academy of Sciences.

[13] http://www.fs.fed.us/r2/news/2010/jan/nr-foresthealth-pressconf-1-22-10.pdf

[14] Another critical finding from the 2009 USGCRP Global Climate Change Impacts in the United States is: "Climate change will interact with many social and environmental stresses. Climate change will combine with pollution, population growth, overuse of resources, urbanization, and other social, economic, and environmental stresses to create larger impacts than from any of these factors alone"

[15] Rajagopalan, B., K. Nowak, J. Prairie, M. Hoerling, B. Harding, J. Barsugli, A. Ray, and B. Udall (2009), Water supply risk on the Colorado River: Can management mitigate?, Water Resour. Res., 45, W08201, doi:10.1029/2008WR007652

underway, one on the Colorado, one on the Milk-St. Marys in Montana, and one on the Yakima in Washington. The Colorado River study is a two-year $2m effort with $1m from Reclamation and $1m from stakeholders. The Colorado River effort is critically important; however, $2m is nowhere near enough funding to meet the objectives of the study which are: "to conduct a comprehensive study to define current and future imbalances in water supply and demand in the Colorado River Basin and the adjacent areas of the Basin States that receive Colorado River water for approximately the next 50 years, and to develop and analysis adaptation and mitigation strategies to resolve those imbalances."[16] By comparison, the Australians recently spent $AUD 12m on a comparable study of their "Colorado River", the Murray-Darling.[17]

In FY2010 Reclamation will spend $6m on these Basin Studies and affiliated work, and in FY2011 $9m is requested[18]. According to Reclamation's proposed budget, these funds will cover state of the art projections of supply and demand, analysis of climate change impacts to existing water and power operations, development of options to improve operations and infrastructure and an analysis of the tradeoffs of different options. In addition, these same funds are expected to provide a West-wide climate risk assessment to complement the Basin Studies. Finally these same funds are expected to support two Landscape Conservation Cooperatives in the Colorado River Basin. While I applaud all of these goals, $6m or even $9m is not nearly enough to support all of these activities.

Independent Scientific Review and Innovative Research

Universities can provide much needed independent reviews on federal science products and can serve as both a source and a sounding board for innovative new ideas. For example, The University-based Western RISAs were recently asked by Reclamation to review Reclamation's new literature synthesis on climate change implications for Reclamation's water resources[19]. Our work for Reclamation on the 2007 Colorado River Shortage Sharing and Coordinated Reservoir Operations EIS included a roadmap and guidance for future research areas by Reclamation[20].

The scientific process depends on independent scientific review. This activity must be supported by DOI's climate initiative if it is to achieve its full potential. This is a relatively low cost activity and Reclamation's Denver-based Science and Technology office has provided financial support for independent review to the RISAs in the past. Presumably such activities will be supported in the future.

Universities are also important for asking hard policy questions that are considered too politically perilous for other institutions. Harvard's water policy expert Peter Rogers once said, "One cannot overestimate the tremendous influence of institutions in delineating the boundaries of federal water policy. Long-established organizations, with time-test outlooks and ways of

[16] http://www.usbr.gov/lc/region/programs/crbstudy/pos.pdf
[17] http://www.nwc.gov.au/www/html/410-murray-darling-basin-sustainable-yields-project.asp?intSiteID=1
[18] See Reclamation FY2011 Budget, Bureauwide Description, page 78 for details.
[19] http://www.usbr.gov/research/docs/climatechangelitsynthesis.pdf
[20] See Appendix U, Chapter 10, Recommendations for Research and Development, http://www.usbr.gov/lc/region/programs/strategies/FEIS/index.html

operating, provide the matrix within which water policy is articulated. Unfortunately, they also serve as constraints upon the development of creative policy options."[21]

I recently traveled to Australia to look at how their water systems have adapted to a very serious ten-year drought. The Australian lessons are fascinating and range from construction of new infrastructure, to a new water ethic, to water markets, to full cost water pricing, to federal purchases of environmental water, and to water policy innovations. In the policy realm, University researchers there eight years ago laid the intellectual framework for many of the water reforms now being enacted in that country[22]. Other water outsiders also helped frame the debate and proposed solutions.[23]

Climate change may require that we rethink how best to manage entire water systems and such thinking is best done by our brightest minds at our universities unconstrained by conventional thinking. For example, my entity plays a role in a new Colorado River Governance initiative being led by the University of Colorado's Natural Resources Law Center to look at how the Colorado River might best operate under very different future conditions. While such efforts may never be fully relevant, in an open society it is critical that such free-thinking work be supported and conducted even though the results may strongly challenge the status quo.

To the best of my knowledge there is no direct budget item in the DOI budget to support such independent innovative research. Such efforts should be sponsored by DOI through the Climate Science Centers and the Landscape Conservation Cooperatives.

Cooperation and Collaboration Among Federal, State, Regional Entities

Cooperation and collaboration are always a tremendous challenge, and the more entities, the bigger the challenge. The diverse nature of the water sector with many local and regional entities, combined with the large number of federal entities – at least 19[24]-- make cooperation and collaboration a particularly vexing problem for anyone working in the field.

While many talk about the difficulty of reducing greenhouse gases ("climate change mitigation"), I strongly believe that a proper price on carbon would allow society to utilize Adam Smith's invisible hand to automatically guide the most efficient resource allocation and best decision making. Climate change adaptation, on the other hand, is far more difficult because it involves the need for cooperation and collaboration among many entities and people. These entities and individuals are typically not used to such efforts.

Climate change adaptation in general is also difficult because it involves understanding the complex way in which impacts interact from sector to sector, e.g., water and energy, water and agriculture. In addition, it requires decision makers and scientists from different sectors be willing and able to communicate in a common technical language, supported by shared scientific studies and understanding. Finally, it also requires a mutual appreciation of the

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[21] P. Rogers, *America's Water, Federal Roles and Responsibilities*, 1993, MIT Press.
[22] See, for example, the Wentworth Group, http://www.wentworthgroup.org/about-us
[23] See the water section from the Hilmer Report from the National Competition Council. http://ncp.ncc.gov.au/pages/water
[24] For a list see Udall and Averyt, 2009, A Critical Need: A National Interagency Water Plan. http://www.swhydro.arizona.edu/archive/V8_N1/feature1.pdf

cultural perspectives of each group. For all of these reasons, significant resources are needed to support these cooperation and collaborative cross-entity activities.

My entity has already made substantial headway establishing the necessary mechanisms to cooperate with Reclamation and the USGS. We have an outstanding relationship with Reclamation that goes back over five years and includes their Lower Colorado River office as well as the Denver Science and Technology center. We now share three postdoctoral researchers jointly funded by Reclamation and NOAA. Next week we will jointly host a conference with Reclamation and the USGS in Boulder bringing together all federal researchers working on Colorado River issues to discuss coordination. In 2007 we began an effort to reconcile the various projections of the future reductions on Colorado River flow. This is a very productive relationship between Reclamation, NOAA, and RISAs at the University of Colorado, the University of Arizona, the Scripps Institution of Oceanography, and the University of Washington.

The large number of institutions concerned about climate change and the inherent difficulty of climate change adaptation mean that the federal government must vigorously pursue more cooperation and collaboration among the various agencies that work on water issues. Executed properly, DOI's Climate Science Centers and Landscape Conservation Cooperatives will go a long ways to providing this coordination and collaboration but such efforts must be supported by resources.

Recommendations and Conclusion

Water is a critical resource for the nation and is already under stress from numerous causes. Climate change will provide yet another water stress, with some of the future climate-related impacts known and some unknown. Reclamation and the USGS will play a critical role in providing research and tools to assist with the water management stresses of the 21st century.

DOI is to be congratulated for its bold effort to tackle climate change including the establishment of Climate Science Centers and Landscape Conservation Cooperatives. It is exciting that Reclamation has been given responsibility for the two Landscape Conservation Cooperatives in the Colorado River Basin. Reclamation is making a good faith effort to implement the SECURE Water Act, although the current and projected funding seems inadequate for the task at hand.

The NOAA-funded RISAs already do much of what the Climate Science Centers and Landscape Conservation Cooperatives propose to do. We have provided stakeholders in our regions numerous products and services during our twelve-plus years of existence. We have strongly supported Reclamation and USGS activities in the past and will continue to do so in the future.

Peter Rogers in his excellent 1993 book on water policy, *America's Water: Federal Roles and Responsibilities*, said, "Successful polices are often impeded not by lack of resources or technology or an insufficiency of economic approaches, but rather by lack of coordination."[25]

[25] Page 175

To avoid overlap, and encourage additional collaboration and cooperation beyond that already existing, DOI should commit resources to cooperation and collaboration with existing climate science efforts, including the NOAA-funded RISA program.

Thank you for the opportunity to address you today, and I look forward to your questions.

Bradley Udall Biographical Sketch

Brad Udall is on the research faculty at the University of Colorado where he serves as the Director of the CU-NOAA Western Water Assessment. The Assessment is an interdisciplinary NOAA-funded project with researchers from NOAA, CU, Colorado State University and the University of Utah . It is designed to assist water managers and other users of climate data and information. The Assessment was recently successfully re-competed by NOAA for another five-year term, subject to congressional appropriations[26].

Brad wrote the water sector chapter of the recently released U.S. Global Change Research Program Global Climate Change Impacts in the United States. He was also an author of *Climate Change in Colorado, A Synthesis to Support Water Resources Management and Adaptation* written for the Colorado Water Conservation Board. His research focuses on Colorado River hydrology, climate, law, and policy. He serves on the Water Research Foundation Expert Panel on Climate Change and has served as an advisor to the Water Utility Climate Alliance. He has given numerous presentations on the impacts of climate change on water resources to such diverse groups as National Academy of Sciences climate-related panels, the Western Governors' Association, U.S. Conference of Mayors, and numerous scientific conferences.

Brad has an engineering degree from Stanford and an MBA from Colorado State University. He was formerly a consulting engineer and the managing partner at Hydrosphere Resource Consultants, where he worked on interstate litigation on the North Platte River, endangered species on the Columbia River, future Front Range supplies, and shortage issues on the Colorado River. He was awarded the Climate Science Service Award from the California Department of Water Resources and he accepted the Partners in Conservation Award from DOI in 2009 on behalf of the Western Water Assessment.

[26] **http://wwa.colorado.edu/RISA_rebid/home.html**