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Sustainability and climate models for the Intermountain West: An annotated bibliography

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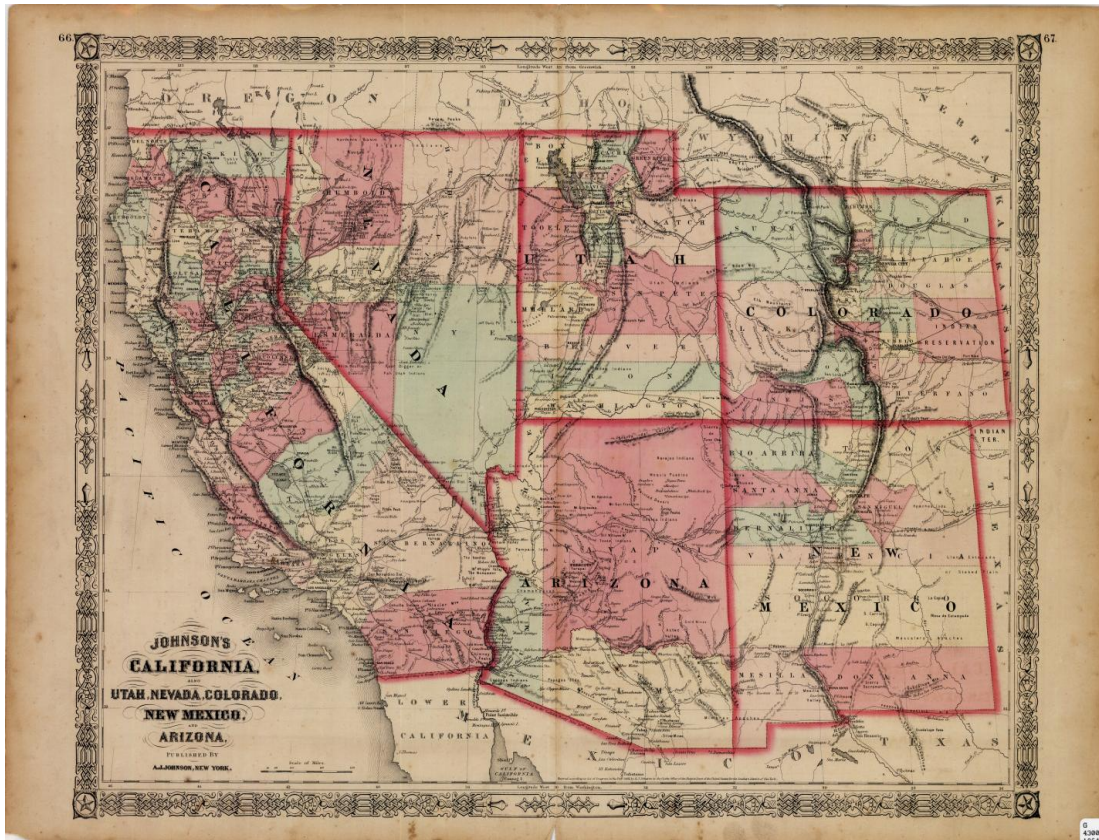
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Sustainability and Climate Models for the Intermountain West -An Annotated Bibliography-

Marianne A. Buehler & William E. Brown, Jr.
November 2011



Johnson's California, with Utah, Nevada, Colorado, New Mexico, and Arizona (1867).
Courtesy of the University of Nevada, Las Vegas Libraries Special Collections

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Sustainability and Climate Models for the Intermountain West

Introduction

This resource on climate models and sustainability in the Intermountain West, a region that includes the states of Arizona, Colorado, Idaho, Nevada, New Mexico, and Utah, is a collaborative effort between the UNLV Libraries (<http://library.unlv.edu/>) and Brookings Mountain West (<http://brookingsmtnwest.unlv.edu/>).

The selected citations include academic, government, and non-profit information that highlight ongoing research on climate models and sustainability efforts in the region. The websites, government studies, independent reports, scholarly articles, and media reports reflect the diversity and complexity of climate change and sustainability issues in a region that contains widely varying ecosystems. The Intermountain West, with its deserts, basins, mountains, metropolitan centers, and rural areas is a microcosm of our nation's terrain, with the obvious and notable exception of a coastal region. Although, as studies show, the Intermountain West is not immune to climate shifts originating in nearby coastal areas.

The citations provided herein include annotated descriptions designed to assist the reader in evaluating the utility of each resource. It is our intention to update this information on a regular basis, as new information and resources are identified.

Brookings Mountain West staff proposed the creation of this resource in Spring 2011 and Marianne Buehler, Urban Sustainability Librarian for the UNLV Libraries, led the research effort to identify and evaluate available resources on these topics. Buehler, in partnership with Bill Brown, Director of Planning and Communication at Brookings Mountain West, refined the list and annotations, with the invaluable assistance of Chris Galvan, a sociology doctoral candidate at UNLV.

Websites & Blogs

Arizona



Hoover (not Boulder) Dam from the Arizona side (1937 or 1938?).
Courtesy of the University of Nevada, Las Vegas Libraries Special
Collections: http://digital.library.unlv.edu/objects/lv_water/865

1. Arizona Water Institute: Arizona's three universities focused on sustainability.
<http://www.azwaterinstitute.org/>
2. Collaborative Research: Assessing Decadal Climate Change Impacts on Urban Populations in the Southwestern USA <http://sustainability.asu.edu/research/project.php?id=517>
3. Decision Center for a Desert City <http://dcdc.asu.edu/index.php>
Conducting climate, water, and decision research and developing innovative tools to bridge the boundary between scientists and decision makers and put our work into the hands of those whose concern is for the sustainable future of Greater Phoenix.
4. Sustainable Tucson: Water articles and other resources
<http://www.sustainabletucson.org/affinity/water/>
5. The Water Plight of Phoenix <http://www.columbia.edu/~kk2534/Phoenix%20Water/index.html>. This

website serves as a source of information regarding the past, present and future of this vanishing water resource in the desert. It will also explore the vast population's dependence on water and potential outlooks from current statistics.

6. Water Resources Research Center, University of Arizona: Publications, newsletters, and more
<http://www.ag.arizona.edu/azwater/>

Colorado



Lake Granby Marina, Colorado, Bill Green. With permission from Water Resources Archive, Colorado State University, Archives and Special Collections: <http://hdl.handle.net/10217/37843>.

1. Climate Preparedness Project <http://www.coloadaptationprofile.org/>
The Colorado Climate Preparedness Project was undertaken by the Western Water Assessment for the State of Colorado. The primary purpose of this project is to assist Colorado in continuing to prepare itself for climate variability and change by providing a catalog of climate vulnerabilities and current activities, including personnel, products and projects from Colorado and other appropriate entities. The project focuses on five sectors: agriculture, electricity, forests/wildlife/ecosystems, tourism/recreation, and water. Provides a wealth of information from numerous projects under the “projects,” “organizations,” and “products” tab. “The Colorado Climate Preparedness Project was undertaken by the Western Water Assessment for the State of Colorado. The primary purpose of this project is to assist Colorado in continuing to prepare itself for climate variability and change by providing a catalog of climate vulnerabilities and current activities, including personnel, products and projects from Colorado and other appropriate entities.”
2. The Colorado Climate Center was established by the state in 1974, through the Colorado State University Agricultural Experiment Station, to provide information and expertise on Colorado’s complex climate. Through its threefold program of Climate Monitoring (data acquisition, analysis, and archiving), Climate Research and Climate Services, the Center is responding to many climate related questions and problems affecting the state today. <http://ccc.atmos.colostate.edu/>
3. Colorado Division of Water Resources <http://water.state.co.us/Home/Pages/default.aspx>

Also known as the *Office of the State Engineer*, administers water rights, issues water well permits, represents Colorado in interstate water compact proceedings, monitors stream-flow and water use, approves construction and repair of dams and performs dam safety inspections, issues licenses for well drillers and assures the safe and proper construction of water wells, and maintains numerous databases of Colorado water information.

4. Colorado River District <http://www.crwcd.org/>

To lead in the protection, conservation, use and development of the water resources of the Colorado River basin for the welfare of the District, and to safeguard for Colorado all waters of the Colorado River to which the state is entitled.

5. U.S. Geological Survey: Colorado Drought Watch <http://co.water.usgs.gov/drought/>
Bureau of Reclamation <http://www.usbr.gov/uc/feature/drought.html>

6. The Water Information Program for Southwest Colorado <http://www.waterinfo.org/indian.html>
Competing water uses from the Colorado River system have defined Colorado history for over 100 years. The legal right to divert and use water in Colorado has been deliberated and defined from before the time of statehood in 1876.

7. Western Water Assessment: Intermountain West Climate Summary

<http://www.colorado.edu/IWCS/>. “Provides the latest climate information in a simple, compact document aimed at water managers, planners, and policy makers with water-related interests.”

“A cool, wet April delayed melt and added to the snowpack across most of the region’s mountains. As a result, May 1st snow packs in the three-state region increased from the April 1st levels, and are much above average in all but southeastern Utah and southern Colorado. The most dramatic increases have been in Wyoming, northern Utah, and northern Colorado.” Also includes drought and precipitation predictions, visual aids, and a wealth of information on climate conditions in the Intermountain West.

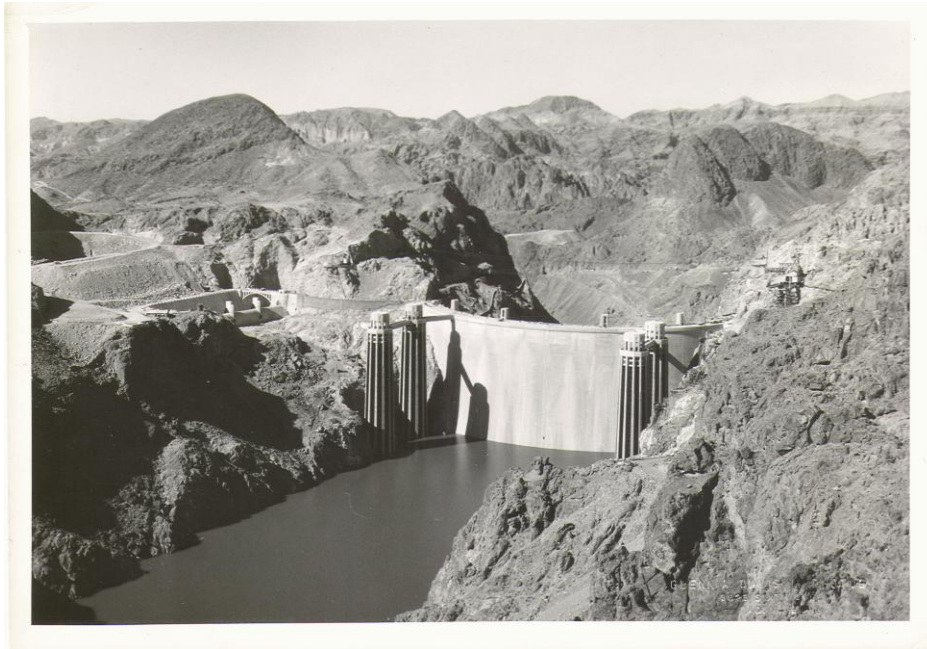
Idaho



Mesa dam and ditch take-off on Middle Fork Weiser River, Idaho, located approximately 7 miles by road above U.S. 95. Mesa dam and ditch take-off (08-24-1941). Courtesy of the University of Oregon Libraries:
http://oregondigital.org/cdm4/item_viewer.php?CISOROOT=/streamsurve&CISOPTR=5.

1. Idaho Water Center <http://www.uidaho.edu/boise/aboutus/idahowatercenter>
Idaho's center of collaboration among government, business and higher education, is dedicated to research, scholarship and service to Idaho and the nation.
2. Idaho Water Resource Board
http://www.idwr.idaho.gov/waterboard/WaterPlanning/StateWaterPlanning/State_Planning.htm
The Idaho Water Resource Board is charged with the development of the Idaho Comprehensive State Water Plan. The plan includes the statewide water policy plan and associated component basin and water body plans which cover specific geographic areas of the state and years: 1972-current plans.
3. Managing Water in the West: Final Boise/Payette Water Storage Assessment Report 2006, U.S. Department of the Interior Bureau of Reclamation Pacific Northwest Region. This assessment is just one activity and one aspect of the many activities that multiple agencies are conducting to address water supply and water management issues in the Boise and Payette River Basins.
http://www.usbr.gov/pn/programs/srao_misc/bp.../FinalBoisePayetteRpt.pdf
4. Water Resources in a Changing Climate (Idaho climate change): EPScOR research. Goal is to improve the statewide research infrastructure for understanding the effects of climate change on water resources in our region and the impact of these effects of ecological, human and economic systems.
<http://www.idahoclimatechange.org/>

Nevada



Telephoto view of Hoover Dam from the upstream side showing the completed intake towers (1936?). Courtesy of the University of Nevada, Las Vegas Libraries Special Collections:
http://digital.library.unlv.edu/objects/lv_water/678.

1. "Climate modeling" Desert Research Institute (Reno)
<http://climatemodeling.blogspot.com/2011/04/integrated-system-model-framework-and.html> John Mejia. Development and implementation of "statistical" and Regional Climate Model downscaling techniques using Global Climate Modeling output from the CMIP3 and CMIP5 into space scales relevant for regional and local impact studies.
2. "It's All Water: Demonstration of an Innovative Treatment Technology for Water Banking in Nevada." Vijay Sundaram, P.E. and John P. Enloe, P.E., ECO:LOGIC Engineering <http://nvwea.org/sswe-newsletters-detail/3034-its-all-water> Water shortages forecast for the west and the possibility of extended drought pose serious challenges for Nevada. Potential water shortages can be addressed in the immediate future by insightful management of available freshwater resources, and recycling or banking "once used" water resources (e.g., reuse of municipal effluent).
3. Nevada Climate Change Portal: The focus of this website is to advance the quality, and quantity of infrastructure and data collection for climate, hydrological and ecological information pertaining to the state of Nevada. This website provides information on the Nevada Climate Change Project and access to both the NevCAN (Nevada Climate-ecohydrology Assessment Network) and climate modeling output.
<http://www.sensor.nevada.edu/NCCP/>

New Mexico



Ancient irrigation ditch near Ruidoso Creek, Southern New Mexico. By one estimate, the ditch may be as much as 2000 years old. Photo date: 1929.

More information and permissions:

http://econtent.unm.edu/cdm4/item_viewer.php?CISOROOT=/NMWaters&CISOPTR=3506.

1. Evaluating the Sustainability of the Albuquerque Water Supply.
<http://www.challenge.nm.org/archive/00-01/FinalReports/013/> The people of this state use too much water from the aquifer from which most of the state's water is pumped. As the water supply dwindles, the population grows. How long until this issue becomes a serious problem? In Albuquerque, New Mexico, the government has seen this problem and is taking steps to fix it.
2. Water, Growth and Sustainability: Planning for the 21ST Century (Santa Fe)
New Mexico: Water Resources Research Institute 12-2000
<http://wrri.nmsu.edu/publish/watcon/proc45/ohare.pdf> "I think we probably have the most severe water shortage emergency of any large city within the state and have implemented water use restrictions I want to share with you."
3. New Mexico EPSCoR and Climate Modeling:
A central research challenge of NM EPSCoR is to understand how future changes in seasonal temperature and precipitation will impact snowpack, snowmelt and spring runoff in the mountainous region of north central New Mexico. This region, the southernmost extent of the Rocky Mountain range, serves as the headwaters for river systems of crucial importance to NM, including the Rio Grande.
<http://nmepscor.org/content/hydrology-and-climate-modeling>

4. University of New Mexico LibGuide: USGS and EPA Mexico water resource data, snow survey, climate information, and more. <http://libguides.unm.edu/content.php?pid=15497&sid=199424>

Utah



Lake Powell (1954-1972). Courtesy of Colorado State University Libraries: <http://hdl.handle.net/10217/26288>.

1. Climate Research Group: University of Utah studies climate and climate change with a focus on atmospheric dynamics include projects, presentations, and publications.

<http://www.inscc.utah.edu/~reichler/research/research.shtml> Additional posters and talks:
http://www.inscc.utah.edu/~reichler/talks/tjr_talks.shtml

2. League of Women Voters of Utah Water Study, September 2009.

http://www.lwvutah.org/AirWaterIssues/lwvutWaterStudy_10-10-19.pdf

“In 2008 the League of Women Voters of Utah decided to do a study of Utah water so that we could better advocate for our members’ deep concerns about water for people and water for the environment. This paper is concerned with accounting for our water and how we manage it, not with water quality either for human uses or for wildlife... Utah is the second driest state in the nation; Utah has the second highest per capita water use. However, we are told to expect more people, and the climate section will show that Utah can most likely expect longer, hotter droughts at the least and more likely a hotter, drier climate overall. The outcomes from the models vary from severe drought with dire consequences to more moderate declines in precipitation that, although serious, may be manageable. Scientists and most water managers agree that global warming will bring higher temperatures to all of Utah. Most of Utah’s usable water comes from snowpack. The state’s system of reservoirs fills in late spring and early summer from the slow snowmelt. The water level in the reservoirs starts to be drawn down beginning in late summer, through the rest of the year and into the next spring. The system depends upon a substantial snowfall and the timing of the spring snow melt. Little snow or more precipitation falling as rain does not allow for timely storage in Utah’s high mountain reservoirs or for efficient seasonal allocation. If Utah has a hotter and drier climate, there will be less water in any form, a smaller snowpack, and probably higher human usage to counter the hotter, drier weather. Even if Utah

were to be warmer but wetter, there are problems. More precipitation will fall as rain rather than snow, filtering through the ground to our aquifers not to our reservoirs, where it is more accessible to the water delivery system now in place. The smaller snowpack will melt early, and since Utah receives little summer moisture, it is likely that summer water use will still be high and long.... The Governor's Office of Planning and Budget projects that the population will grow from 2,833,337 in 2010 to 5,368,567 in 2050, mostly on the Wasatch Front (GOPB, 2009).” “Water usage is highest in dry states due to precipitation, which has increased due to global warming. Tucson has low per capita water use, and Utah's dropped from 293 gpcd in 2000 to 260 gpcd in 2005 (UDWR (2009) Weber R. Basin, p. 47). Both are largely attributable to efficiencies achieved by both suppliers and consumers of water.”

3. Utah State University Climate Center <http://climate.usurf.usu.edu/>

The mission of the Utah Climate Center (UCC) is to facilitate access to climate data and information, and to use expertise in atmospheric science to interpret climate information in an accurate and innovative fashion for the public. The mission includes the design of new products to meet present and future needs of agriculture, natural resources, government, industry, tourism, and educational organizations in Utah and the intermountain region.

4. University of Utah-SCI (Scientific Computing and Imaging) Institute <http://www.sci.utah.edu/>

The Scientific Computing and Imaging (SCI) Institute is a permanent research institute at the University of Utah. Directed by [Professor Chris Johnson](#), the Institute is now home to [over 190 faculty, students, and staff](#). The faculty, drawn primarily from the [School of Computing](#), [Department of Bioengineering](#), and [Department of Electrical and Computer Engineering](#), is noted for its breadth of collaborations both nationally and internationally. The SCI Institute has established itself as an internationally recognized leader in visualization, scientific computing, and image analysis. The overarching research objective is to create new scientific computing techniques, tools, and systems that enable solutions to problems affecting various aspects of human life. A core focus of the Institute has been biomedicine, but SCI Institute researchers also solve challenging computational and imaging problems in such disciplines as geophysics, combustion, molecular dynamics, fluid dynamics, and atmospheric dispersion.

Western States

1. Southwest Climate Change NETWORK: Climate, impacts, solutions, articles featured and library tabs with more information. Recognizing the growing need for information about our changing climate, the Institute of the Environment and the Climate Assessment for the Southwest (CLIMAS) at The University of Arizona developed and jointly administer the Southwest Climate Change Network. The Institute of the Environment is a cross-campus and community resource and a catalyst in the area of environment and society; it promotes both disciplinary and interdisciplinary research relating to the Earth's environment, from local to global scales, and how this environment is likely to change in coming seasons, years, and decades. CLIMAS is a project housed within the Institute and funded by the U.S. National Oceanic and Atmospheric Administration to carry out stakeholder-driven interdisciplinary climate research. Since 1998, CLIMAS has contributed to the Southwest's ability to respond sufficiently and appropriately to climatic events and climate changes. <http://www.southwestclimatechange.org/>
3. United States Global Change Research Program <http://www.globalchange.gov/> Integrating federal research and solutions for climate and global change: The U.S. Global Change Research Program (USGCRP) coordinates and integrates federal research on changes in the global environment and their implications for society. Contains reports and publications.
4. U.S. Department of the Interior. Bureau of Reclamation. Water Smart Program. West-Wide Climate Risk Assessments. <http://www.usbr.gov/WaterSMART/wwcra.html>
5. The West-Wide Climate Risk Assessments (WWCRA) are a complementary activity with the Basin Studies and the Landscape Conservation Cooperatives within the WaterSMART Initiative, in accordance with [Secretarial Order 3289](#) (and meet the authorizations of the Secure Water Act. As a whole, these three activities represent a comprehensive approach to incorporate the best available science into planning activities for climate change adaptation planning.
6. Western States Water Laws <http://www.blm.gov/nstc/WaterLaws/>
This website reviews the water laws of eleven western states (Alaska, Arizona, California, Colorado, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, and Wyoming). Special attention is paid to the states' water rights systems, the application processes, groundwater regulations, the general adjudication processes, and the states' in-stream flow programs.
7. Links to a variety of Western Water Resources Issues: Water resource centers, water plans, dams, drought, groundwater, water quality, state water resources, environmental organizations, federal agencies, and conservation. <http://web.hwr.arizona.edu/globe/h2oissues.html>

Scholarly Articles & Books

1. "A regional climate model for the western United States," Robert E. Dickinson, Ronald M. Errico, Filippo Giorgi, and Gary T. Bates. *Climatic Change*, Volume 1, 1977, Volume 106, 2011, pp. 383-422. <http://www.springerlink.com/content/v112217p34405205/> A numerical approach to modeling climate on a regional scale is developed whereby large-scale weather systems are simulated with a global climate model (GCM) and the GCM output is used to provide the boundary conditions needed for high-resolution mesoscale model simulations over the region of interest. In our example, we use the National Center for Atmospheric Research (NCAR) community climate model (CCM1) and the Pennsylvania State University (PSU)/NCAR Mesoscale Model version 4 (MM4) to apply this approach over the western United States (U.S.). The topography, as resolved by the 500-km mesh of the CCM1, is necessarily highly distorted, but with the 60-km mesh of the MM4 the major mountain ranges are distinguished. To obtain adequate and consistent representations of surface climate, we use the same radiation and land surface treatments in both models, the latter being the recently developed Biosphere-Atmosphere Transfer Scheme (BATS). Our analysis emphasizes the simulation at four CCM1 points surrounding Yucca Mountain, NV, because of the need to determine its climatology prior to certification as a high-level nuclear waste repository. We simulate global climate for three years with CCM1/BATS and describe the resulting January surface climatology over the Western U.S. The details of the precipitation patterns are unrealistic because of the smooth topography. Selecting five January CCM1 storms that occur over the western U.S. with a total duration of 20 days for simulation with the MM4, we demonstrate that the mesoscale model provides much improved wintertime precipitation patterns. The storms in MM4 are individually much more realistic than those in CCM1. A simple averaging procedure that infers a mean January rainfall climatology calculated from the 20 days of MM4 simulation is much closer to the observed than is the CCM1 climatology. The soil moisture and subsurface drainage simulated over 3–5 day integration periods of MM4, however, remain strongly dependent on the initial CCM1 soil moisture and thus are less realistic than the rainfall. Adequate simulation of surface soil water may require integrations of the mesoscale model over time periods.
2. "An approach toward a rational classification of climate." C. W. Thornthwaite. *Geographical Review*, Vol. 38, No. 1 (Jan., 1948), pp. 55-94. Published by: American Geographical Society. Includes Western climatic charts/graphs. The sum of the climatic elements that have been under observation does not equal climate. <http://www.jstor.org/stable/210739>
3. "Climate Change, Water, and Risk: Current Water Demands Are Not Sustainable," Natural Resources Defense Council, July 2010. Climate change will have a significant impact on the sustainability of water supplies in the coming decades. A new analysis, performed by consulting firm Tetra Tech for the Natural Resources Defense Council (NRDC), examined the effects of global warming on water supply and demand in the contiguous United States. The study found that more than 1,100 counties—one-third of all counties in the lower 48—will face higher risks of water shortages by mid-century as the result of global warming. www.nrdc.org/globalwarming/watersustainability/files/WaterRisk.pdf
4. "Dry Times Ahead," Jonathan Overpeck and Bradley Udall, *Science*, Vol. 328, p. 1642, 25 June 2010. <http://www.sciencemag.org/content/328/5986/1642.short>

“In the past decade, it has become impossible to overlook the signs of climate change in western North America. They include soaring temperatures, declining late-season snowpack, northward-shifted winter storm tracks, increasing precipitation intensity, the worst drought since measurements began, steep declines in Colorado River reservoir storage, widespread vegetation mortality, and sharp increases in the frequency of large wildfires. These shifts have taken place across a region that also saw the nation's highest population growth during the same period.”

5. “Global Warming Coming Home to Roost in the American West” (CA). Richard A. Kerr. *Science* 21 December 2007: <http://www.sciencemag.org/content/318/5858/1859.full>

6. "Human-Induced Changes in the Hydrology of the Western United States" Tim P. Barnett, et al. *Science Magazine* Report. *Science* 22 February 2008: Vol. 319 no. 5866 pp. 1080-1083. DOI: 10.1126/science.1152538. Observations have shown that the hydrological cycle of the Western United States changed significantly over the last half of the 20th century. We present a regional, multivariable climate change detection and attribution study, using a high-resolution hydrologic model forced by global climate models, focusing on the changes that have already affected this primarily arid region with a large and growing population. *Includes additional full-text articles citing this article.* <http://www.sciencemag.org/content/319/5866/1080.short>

7. “Hydroclimate of the Western United States Based on Observations and Regional Climate Simulation of 1981–2000 “ *Journal of Climate*, V 16, Issue 12. Part I: Seasonal Statistics L. Ruby Leung, Yun Qian, and Xindi Bian. Pacific Northwest National Laboratory, Richland, Washington. Provides detailed analyses of observations and regional climate simulations to improve our understanding and modeling of the climate of this region. <http://journals.ametsoc.org/doi/full/10.1175/1520-0442%282003%29016%3C1892%3AHOTWUS%3E2.0.CO%3B2>

8. "Identifying and evaluating robust adaptive policy responses to climate change for water management agencies in the American west," Robert J. Lempert and David G. Groves. *Technological Forecasting and Social Change*, Volume 77, Issue 6, July 2010, Pages 960-974.

Climate change presents a significant planning challenge for water management agencies in the Western United States. Changing precipitation and temperature patterns will disrupt their supply and extensive distribution systems over the coming decades, but the precise timing and extent of these impacts remain deeply uncertain, complicating decisions on needed investments in infrastructure and other system improvements. Adaptive strategies represent an obvious solution in principle, but are often difficult to develop and implement in practice. This paper describes work helping the Inland Empire Utilities Agency (IEUA) explicitly develop adaptive policies to respond to climate change and integrating these policies into the organizations' long-range planning processes. The analysis employs Robust Decision Making (RDM), a quantitative decision- analytic approach for supporting decisions under conditions of deep uncertainty. RDM studies use simulation models to assess the performance of agency plans over thousands of plausible futures, use statistical “scenario discovery” algorithms to concisely summarize those futures where the plans fail to perform adequately, and use these resulting scenarios to help decision makers understand the vulnerabilities of their plans and assess the options for ameliorating these vulnerabilities. This paper demonstrates the particular value of RDM in helping decision makers to design and evaluate adaptive strategies. For IEUA, the RDM analysis suggests the

agency's current plan could perform poorly and lead to high shortage and water provisioning costs under conditions of: (1) large declines in precipitation, (2) larger-than-expected impacts of climate change on the availability of imported supplies, and (3) reductions in percolation of precipitation into the region's groundwater basin. Including adaptivity in the current plan eliminates 72% of the high-cost outcomes. Accelerating efforts in expanding the size of one of the agency's groundwater banking programs and implementing its recycling program, while monitoring the region's supply and demand balance and making additional investments in efficiency and storm-water capture if shortages are projected provides one promising robust adaptive strategy—it eliminates more than 80% of the initially-identified high-cost outcomes. <http://www.sciencedirect.com/science/article/pii/S0040162510000740>

10. "Mid-century ensemble regional climate change scenarios for the Western United States," L. Ruby Leung, et al. *Climatic Change*, Volume 62, Numbers 1-3, 75-113, 2004. Describes the regional simulations and focuses on the hydro-climate conditions in the Columbia River Basin (CRB) and Sacramento-San Joaquin River (SSJ) Basin. From fws.gov: http://www.fws.gov/filedownloads/ftp_region6_upload/FOIA%20READING%20ROOM/FOIA%202010/American%20Pika%2012%20Month/12%20month%20status%20review%20citations/Leung%20et%20al%202004.pdf

11. "Multi-decadal Regime Shifts in U.S. Streamflow, Precipitation, and Temperature at the End of the Twentieth Century." Mauget, Steven A., 2003: *J. Climate*, 16, 3905–391. Covers years: 1896–2001. During the late 1980s and early 1990s, a significant incidence of low-ranked annual flow conditions throughout the West was roughly coincident with the onset of Western warmth during the mid-1980s. Evidence of highly significant transitions to wetter and warmer conditions nationally, and consistent variation in stream flow analyses, suggests that increased hydrological surplus in the Central and Eastern United States and increased hydrological deficit in the West may be representative of the initial stages of climate change over the continental United States. <http://journals.ametsoc.org/doi/abs/10.1175/1520-0442%282003%29016%3C3905%3AMRSIUS%3E2.0.CO%3B2>

Resolving the Water Dilemma: Past Problems and Future Trends (with Richard Acton), in *Public Policy in Nevada: Looking Towards the Year 2000 and Beyond* (Dennis L. Soden and Eric Herzik, eds.). Dubuque: Kendall-Hunt Publishers, 1997.

12. "Water, Growth and Sustainability: Planning for the 21ST Century," Eluid Martinez, *Water Issues in the West*. December 2000. New Mexico Water Resources Research Institute. <http://wrrri.nmsu.edu/publish/watcon/proc45/martinez.pdf>

13. *The Water Challenge: Contemporary Issues in Northern Nevada* (with Richard Acton), in *Public Policy in Nevada: The New Millennium* (Dennis L. Soden and Eric Herzik, eds.). Dubuque: Kendall-Hunt Publishers, 2000.

14. "Trends in the Hydrology of the Western U.S. Bear the Imprint of Manmade Climate Change." Barbara Goss Levi, *physicstoday*, April 2008. http://physicstoday.org/resource/1/phtoad/v61/i4/p16_s1

15. *Colorado River Basin Water Management: Evaluating and Adjusting to Hydroclimatic Variability*, Committee on the Scientific Bases of Colorado River Basin Water Management, National Research Council, 222 pages. Recent studies of past climate and stream-flow conditions have broadened

understanding of long-term water availability in the Colorado River, revealing many periods when stream-flow was lower than at any time in the past 100 years of recorded flows. That information, along with two important trends—a rapid increase in urban populations in the West and significant climate warming in the region—will require that water managers prepare for possible reductions in water supplies that cannot be fully averted through traditional means.

http://www.nap.edu/catalog.php?record_id=1185

16. University of Nevada, Las Vegas faculty research articles on water, drought, and stream-flow in the Western U.S. http://digitalcommons.library.unlv.edu/fac_articles/

Graduate & Institutional Research

Graduate Research

1. Climate change in rural Nevada: The influence of vulnerability on risk perception and environmental behavior, Ahmad Safi. Dissertation, 2011.
<http://digitalcommons.library.unlv.edu/thesesdissertations/906/>
2. Groundwater: Solution to the Las Vegas water problem? Rosa Perez and Christopher Ruiz. Poster, 2011. http://digitalcommons.library.unlv.edu/focs_ug_research/2011/april16/41/

Institutional Research

Nevada NSF EPSCoR Climate Change Project (2008-2013)

1. Climate Change Seminar Series: (Lectures & PowerPoint presentations):
http://digitalcommons.library.unlv.edu/climate_change/
2. EPSCoR Conference (PowerPoint presentations & research posters):
<http://digitalcommons.library.unlv.edu/epscor/>

Government Research

1. Arizona Department of Environmental Quality, Arizona Climate Change Initiatives. The Governor's Policy on Climate Change, Executive Order 2010-06, recognizes the importance of reducing greenhouse gas emissions while maintaining Arizona's economic growth and competitiveness. Increased greenhouse gas emissions, a key driver influencing climate change may result as Arizona's population and economy expands, but Arizona has significant strengths on which to build, including stringent renewable energy standards and one of the nation's most aggressive energy efficiency standards. The Governor's policy supports Arizona's continued collaboration in regional and national endeavors to advance clean energy and implement cost-effective solutions to climate change while safeguarding its unique state interests. The Arizona Department of Environmental Quality has an important role in ensuring clean air, safe water, and better protected land for all Arizonans. Together with Arizona businesses and communities, we strive for pragmatic, pro-active approaches to climate change by advancing clean renewable energy, smart growth, fuel efficient transportation and energy efficiency policies and practices that make sense for Arizona.
http://www.azclimatechange.gov/az_initiatives.html

2. "Climate Change, Water, and Risk: Current Water Demands Are Not Sustainable," Natural Resources Defense Council, July 2010. Climate change will have a significant impact on the sustainability of water supplies in the coming decades. A new analysis, performed by consulting firm Tetra Tech for the Natural Resources Defense Council (NRDC), examined the effects of global warming on water supply and demand in the contiguous United States. The study found that more than 1,100 counties—one-third of all counties in the lower 48 will face higher risks of water shortages by mid-century as the result of global warming. Some states have an extreme or high risk to water sustainability, or are likely to see limitations on water availability as demand exceeds supply by 2050. These areas include parts of Arizona, Arkansas, California, Colorado, Florida, Idaho, Kansas, Mississippi, Montana, Nebraska, Nevada, New Mexico, Oklahoma, and Texas. In particular, in the Great Plains and Southwest United States, water sustainability is at extreme risk. Two of the principal reasons for the projected water constraints are shifts in precipitation and potential evapotranspiration (PET). Evapotranspiration is the sum of evaporative loss of water from the ground surface and transpiration losses through vegetation."
www.nrdc.org/globalwarming/watersustainability/files/WaterRisk.pdf

3. "Climate: Waiting to battle warming "imprudent" NAS warns Congress (05/12/2011.) Lauren Morello, *E&E reporter*. Climate change is real and poses "significant risks" to society, the National Academy of Sciences said today, warning that delaying cuts in greenhouse gas emissions will make dealing with the problem harder in the future." Each additional ton of greenhouse gases emitted commits us to further change and greater risks," the report says. The plain-spoken document, prepared in response to Congress' request for "action oriented" advice, says waiting to combat warming is "imprudent." It calls for the federal government to take a lead role in combating climate change in the United States—which it said cannot be addressed effectively with piecemeal efforts by state and local governments—and abroad." The risks associated with doing business as usual are a much greater concern than the risks associated with engaging in strong response efforts," the report adds. "This is because many aspects of an 'overly ambitious' policy response could be reversed if needed, through subsequent policy change; whereas adverse changes in the climate system are much more difficult (indeed, on the timescale of our lifetimes, may be impossible) to 'undo.'"

The analysis, prepared by a team of scientists, economists and engineers, also weighs in on the state of climate science, which it deems sound—though it says some degree of uncertainty about the rate and severity of future climate change is inevitable." Given the inherent complexities of the climate system, and the many social, economic, technological, and other factors that affect the climate system, we can expect always to be learning more and to be facing uncertainties regarding future risks," the report says. "This is not, however, a reason for inaction." <http://www.eenews.net/eenewspm/rss/2011/05/12/1>

4. Collaborative Management and Research in the Great Basin—Examining the Issues and Developing a Framework for Action. Jeanne C. Chambers, Nora Devoe, and Angela Evenden, editors.
http://www.cabnr.unr.edu/GreatBasinWatershed/Issues_Papers.pdf

"This GTR is the product of the workshop on "Collaborative Watershed Research and Management in the Great Basin" that was held in Reno, Nevada on November 28-30, 2006. Cosponsors included University of Nevada, Reno, Desert Research Institute, Great Basin Cooperative Ecosystems Studies Unit, Utah State University, Agricultural Research Service, Bureau of Land Management, State of Nevada, Department of Wildlife and Game, USDA Forest Service, Region 4, USDA Forest Service, Rocky Mountain Research Station, US Geological Survey."

This file contains a number of reports regarding climate change and sustainability in the Southwestern U.S. In summation: "Because the Great Basin is a semi-arid region, the changing climate is likely to have a greater influence than in more mesic regions. The Great Basin warmed by 0.6 to 1.1F in the last 100 years and is projected to warm by an additional 3 to 6F by the end of this century (Environmental Protection Agency 1998, Wagner 2003). Precipitation increased 6-16% in the last 50 years; it is projected to continue to increase in the future (Baldwin and others 2003). However, snowpack has declined and the decreases in the Great Basin have been among the largest in the nation (Mote and others 2005). Both the onset of spring and the timing of spring snowmelt-driven stream flow are now about 10-15 days earlier than 50 years ago (Cayan and others 2001, Baldwin and others 2003, Stewart and others 2004). In the future it is likely that spring peak flows will be reduced and even earlier as more winter precipitation falls as rain. The frequency of droughts and floods is predicted to increase. These changes in flow regimes will result in management challenges related to water storage, channel maintenance, floods and droughts, pollutants, and biodiversity (Baldwin and others 2003). Water resources now used for hydropower, irrigation, riparian and aquatic habitat and fisheries all may be negatively affected." This report provides a plethora of sources and links to related organizations.

5. "Global Climate Change Impacts in the United States," Thomas R. Karl, Jerry M. Melillo, and Thomas C. Peterson, (eds.). July 2009. Cambridge University Press. (in public domain). This report summarizes the science of climate change and the impacts of climate change on the United States, now and in the future. It is largely based on results of the U.S. Global Change Research Program (USGCRP) and integrates those results with related research from around the world.
downloads.globalchange.gov/usimpacts/pdfs/climate-impacts-report.pdf

"This report summarizes the science of climate change and the impacts of climate change on the United States, now and in the future. It is largely based on results of the U.S. Global Change Research Program (USGCRP) and integrates those results with related research from around the world.... Water supplies

are projected to become increasingly scarce, calling for trade-offs among competing uses, and potentially leading to conflict.” p. 129 begins the discussion of the Southwest.

6. Idaho Payette River Basin Comprehensive State Water Plan: Issues, considerations, and goals
<http://www.idwr.idaho.gov/waterboard/WaterPlanning/CompBasinPlanning/Payette/PDF/Payette%20Resource%20Issues-Goals.pdf>

7. SECURE Water Act Section 9503(c)—Reclamation Climate Change and Water 2011, prepared by the U.S. Dept. of the Interior Bureau of Reclamation.
<http://www.usbr.gov/climate/SECURE/docs/SECUREWaterReport.pdf>

“A recent paper by the Congressional Budget Office summarizes the current understanding of the impacts of climate change in the United States, including that warming will tend to be greater in the interior of the contiguous United States. Temperature and precipitation conditions over Western United States regional drainages are projected to change as the effects of global climate change are realized. Projections of future temperature and precipitation are based on multiple Global Circulation (or Climate) Models (GCMs) and various projections of future greenhouse gas emissions (GHG), technological advancements, and global population estimates. A survey of these models over any of the regional drainages shows that there is model consensus agreement reported between climate model projection.” The report discusses in detail the major Western Basins and relevant predictions. It also provides a number of great visuals. In my limited research, this is the best resource available.

8. University of Nevada, Las Vegas Institutional Repository—various government reports related to water in the Mountain West region, 1945-2009. http://digitalcommons.library.unlv.edu/water_pubs/

9. Utah Department of Environmental Quality: Climate Change Work Group.
The Division of Air Quality received a grant from the Hewlett Foundation to help develop specific policy and program options to document and reduce greenhouse gas emissions in Utah. The grant will help support a stakeholder work group that has been established and provides analytical support to the Governor’s Blue Ribbon Council on Climate Change. The work group also assists the Council in identifying policy and program options. http://www.deq.utah.gov/Issues/Climate_Change/index.htm

10. “Water availability for the Western United States—Key scientific challenges: U.S. Geological Survey Circular 1261” Anderson, Mark T., and Woosley, Lloyd H., Jr., 2005, 85 p.

In the Western United States, the availability of water has become a serious concern for many communities and rural areas. Near population centers, surface-water supplies are fully appropriated, and many communities are dependent upon ground water drawn from storage, which is an unsustainable strategy. <http://pubs.usgs.gov/circ/2005/circ1261/>

11. “Water, Growth and Sustainability: Planning for the 21st Century,” Eluid Martinez, *Water Issues in the West*. December 2000. New Mexico Water Resources Research Institute.
<http://wrri.nmsu.edu/publish/watcon/proc45/martinez.pdf>

12. “West-Wide Climate Risk Assessments: Bias-Corrected and Spatially Downscaled” Surface Water Projections Discusses the technical aspects of modeling predictions. This discussion is very informative if the reader is interested in learning such methodologies. The report also provides the evidence used in

the SECURE water report listed above and a range of visual aids.

<http://www.usbr.gov/WaterSMART/wwcra.html>

13. U.S. Department of the Interior, Bureau of Reclamation: Managing water in the West.

<http://www.usbr.gov/>

14. EPA Climate website: Climate economics, Regulatory initiatives for greenhouse gas emissions, U.S. climate policy, and more. <http://www.epa.gov/climatechange/>

Reports & Studies

1. "Climate Change and Its Implications for New Mexico's Water Resources and Economic Opportunities," Technical Report 45. Brian H. Hurd and Julie Coonrod. New Mexico State University, Las Cruces, New Mexico, August, 2008. Social, economic and environmental systems in water-scarce New Mexico and throughout the arid southwest are vulnerable to disruptions in water supplies that are likely to accompany future climate changes. With a particular focus on potential economic consequences for New Mexico, this study uses a hydro-economic model of the Rio Grande watershed to integrate plausible changes in climate with hydrologic responses and water demands within a framework that optimizes water-use allocations for the greatest economic benefit. The study uses three climate change scenarios across two future time periods selected to represent the range of effects indicated by the outputs across eighteen global climate models (GCMs) using the SRES A1B emissions scenario. These six climate change scenarios were then used to model runoff changes using the WATBAL hydrologic model (Yates, 1996), which integrates climate and hydrologic variables, and to change water demand parameters in the hydro-economic model. Primary findings confirm that ecosystems are at greatest risk in New Mexico, followed by agricultural water users, as water is increasingly transferred to maintain urban and industrial users, whose economic productivity is greater. While total annual economic losses are estimated in the vicinity of \$300 million, under severe climate changes, where runoff is reduced by nearly 30%, both economic and non-economic losses are likely to be significantly higher. This is due primarily to the effects of some strongly optimistic model assumptions, e.g., assuming no conflicts over water rights or water transfers and to several significant and valuable omissions in the analysis, e.g., the environmental and social services that agriculture and the environment provide.

<http://www.law.arizona.edu/adaptationconference/PDFs/HurdCoonrodTR45.pdf>

2. "Climate Change and Utah: The Scientific Consensus," Blue Ribbon Advisory Council on Climate Change (BRAC), Salt Lake City, Utah, September 2007.

As directed by Governor Jon Huntsman's Blue Ribbon Advisory Council on Climate Change (BRAC), this report summarizes present scientific understanding of climate change and its potential impacts on Utah and the western United States. Prepared by scientists from the University of Utah, Utah State University, Brigham Young University, and the United States Department of Agriculture, the report emphasizes the consensus view of the national and international scientific community, with discussion of confidence and uncertainty as defined by the BRAC.

http://www.deq.utah.gov/BRAC_Climate/docs/Final_Report/Sec-A-1_SCIENCE_REPORT.pdf

3. "Economic Impacts of Climate Change on Colorado," July 2008. A Review and Assessment Conducted by the Center for Integrative Environmental Research, University of Maryland.

Policymakers across the country are now seeking solutions to curb greenhouse gas emissions and to help us adapt to the impending impacts triggered by past emissions. The debate to date has primarily focused on the perceived costs of alternative solutions, yet there can also be significant costs of inaction. Climate change will affect our water, energy, transportation, and public health systems, as well as state economies as climate change impact a wide range of important economic sectors from agriculture to manufacturing to tourism. This report, part of a series of state studies, highlights the economic impacts of climate change in Colorado and provides examples of additional ripple effects such as reduced spending in other sectors and resulting losses of jobs, wages, and even tax revenues.

<http://www.cier.umd.edu/climateadaptation/Colorado%20Economic%20Impacts%20of%20Climate%20Change.pdf>

4. "Economic Impacts of Climate Change on Nevada," July 2008. A Review and Assessment Conducted by the Center for Integrative Environmental Research, University of Maryland. Policymakers across the country are now seeking solutions to curb greenhouse gas emissions and to help us adapt to the impending impacts triggered by past emissions. The debate to date has primarily focused on the perceived costs of alternative solutions, yet there can also be significant costs of inaction. Climate change will affect our water, energy, transportation, and public health systems, as well as state economies as climate change impact a wide range of important economic sectors from agriculture to manufacturing to tourism. This report, part of a series of state studies, highlights the economic impacts of climate change in Nevada and provides examples of additional ripple effects such as reduced spending in other sectors and resulting losses of jobs, wages, and even tax revenues.

<http://www.cier.umd.edu/climateadaptation/Nevada%20Economic%20Impacts%20of%20Climate%20Change.pdf>

5. "Growth and Sustainability in the Las Vegas Valley" Sonoran Institute, Tucson, AZ, January 2010. <http://climatechange.education.unlv.edu/sites/default/files/FinalLasVegasReport12-17-09lores.pdf>

6. League of Women Voters of Utah Water Study, September 2009. In 2008 the League of Women Voters of Utah decided to do a study of Utah water so that we could better advocate for our members' deep concerns about water for people and water for the environment. This paper is concerned with accounting for our water and how we manage it, not with water quality either for human uses or for wildlife. http://www.lwvutah.org/AirWaterIssues/lwvutWaterStudy_10-10-19.pdf

7. "The Last Drop: Climate Change and the Southwestern Water Crisis" Frank Ackerman and Elizabeth A. Stanton, Stockholm Environment Institute (SEI) – U.S. Center, Somerville, MA, February, 2011. http://sei-us.org/Publications_PDF/SEI-WesternWater-0211.pdf

8. Nevada: 2010-2011 Policy and Program Report: Water Resources, April 2010-Nevada water law, charts, etc. <http://www.leg.state.nv.us/Division/Research/Publications/.../33-WR.pdf>

9. "Nevada Infrastructure for Climate Change: Science, Education, and Outreach" February 2009. The vision of this project is to create a statewide interdisciplinary program that stimulates transformative research, education, and outreach on the effects of regional climate change on ecosystem services (especially water resources) and support use of this knowledge by policy makers and stakeholders. http://www.nevada.edu/epscor/nsf/ertab/aaas/Piechota_Project%20overview.pdf

10. New Mexico Climate Change Initiatives: Background Information on New Mexico Climate Change Initiatives (5): Recognizing the profound implications that global warming and climate variation could have on the economy, environment and quality of life in the Southwest, New Mexico Governor Bill Richardson signed executive order. <http://www.nmenv.state.nm.us/cc/>

11. Reclamation: Managing Water in the West. SECURE Water Act Section 9503(c) – Reclamation Climate Change and Water 2011. U.S. Department of the Interior Policy and Administration Bureau of Reclamation Denver, Colorado April 2011.

<http://www.usbr.gov/climate/SECURE/docs/SECUREWaterReport.pdf>

12. “Renegotiating Urban Water Management in Flagstaff, Arizona: Origins and Implications of Conservation Policies. Kristen E. Reed, Geography & Regional Development,” University of Arizona. Drawing from archival data, I trace socioeconomic and biophysical factors that led to the implementation of conservation measures in Flagstaff, Arizona. A content analysis of contemporary water problems, their causes, and potential management responses informed by semi-structured interviews with key water policymakers in the area, representatives from community interest groups, and scientists indicates that more than three times as many informants, including those with historically opposing viewpoints, prefer conservation measures over supply augmentation policies.

http://www.usbr.gov/lc/.../09_CL1-04ThesisFlagstaffH2OMngmnt.pdf

13. “Municipal Deliveries of Colorado River Basin Water: New Report Examines 100 Cities and Agencies,” Pacific Institute. Michael J. Cohen, June 2011. The Pacific Institute is one of the world’s leading independent nonprofits conducting research and education to create a healthier planet and sustainable communities documents population and water delivery information and trends for 100 cities and agencies that deliver water from the Colorado River basin. Since 1990, the number of people in the United States and Mexico who use Colorado River basin water has increased by more than 10 million — but their overall per capita water use declined by an average of at least one percent per year from 1990 to 2008. http://www.pacinst.org/reports/co_river_municipal_deliveries/crb_water_8_21_2011.pdf A spreadsheet of data compiling water use and population data and calculating per capita use rates. It also lists the sources for the data used in this report:

http://www.pacinst.org/reports/co_river_municipal_deliveries/

Secondary Sources: Newspaper Articles

1. "Climate change to hit American West water supply." *AlertNet* (Reuters) 25 April 2011 Climate change could cut water flow in some of the American West's biggest river basins—including the Rio Grande and the Colorado—by up to 20 percent this century, the Interior Department reported on Monday. "Irrigation, drinking water to be affected by 2100... Driest areas are also some of most heavily populated... Interior Department calls for conservation, efficiency."
<http://www.trust.org/alertnet/news/climate-change-to-hit-american-west-water-supply>
2. "No, the snow does not disprove global warming" Ezra Klein. *The Washington Post*, February 10, 2010. "In the aggregate, Earth's atmosphere is getting warmer. But that affects particular climates in different ways. What's difficult about getting it to snow isn't temperature, but precipitation. And global warming is expected to increase precipitation."
http://voices.washingtonpost.com/ezra-klein/2010/02/no_the_snow_does_not_disprove.html
3. "Quenching Las Vegas Thirst" Phoebe Sweet. *Las Vegas Sun*. With expected changes in climate and no change in water could run dry by 2021. <http://www.lasvegassun.com/news/topics/water/>
4. "Report: Climate change to sap Utah water supply" *Utah News*. *The Salt Lake Tribune*. April 25, 2011. The Colorado River Basin likely will lose about 9 percent of its annual runoff by mid-century because of a warming climate, further squeezing Utah and its neighbors in a region that already expects to struggle getting water to its growing population, according to a U.S. Interior Department report released Monday.
<http://www.sltrib.com/sltrib/politics/51690000-90/report-colorado-river-climate.html.csp>
5. "The Future Is Drying Up" Jon Gertner. *The New York Times*, October 21, 2007.
<http://www.nytimes.com/2007/10/21/magazine/21water-t.html?pagewanted=print> "The snowpack in the Sierra Nevada, which provides most of the water for Northern California, was at its lowest level in 20 years. Chu noted that even the most optimistic climate models for the second half of this century suggest that 30 to 70 percent of the snowpack will disappear. A catastrophic reduction in the flow of the Colorado River—which mostly consists of snowmelt from the Rocky Mountains—has always served as a kind of thought experiment for water engineers, a risk situation from the outer edge of their practical imaginations. Some 30 million people depend on that water. A greatly reduced river would wreak chaos in seven states: Colorado, Utah, Wyoming, New Mexico, Arizona, Nevada and California. Almost without exception, recent climate models envision reductions that range from the modest to the catastrophic by the second half of this century. One study in particular, by Martin Hoerling and Jon Eischeid, suggests the region is already "past peak water," a milestone that means the river's water supply will now forever trend downward." The author continues with a discussion of economic impacts, including mass out-migration, of water shortages.
6. "Steady State: A Sustainable Economy for the Southwest" Steven Kotler. *Ecoearth*, July 2, 2010. "Western states rely on the Colorado River, but the river is no longer viable. Last year, a study done at the Scripps Institution of Oceanography (published in *Water Resources Research*) compared water usage

to population, then factored in a variety of global-warming possibilities. It concluded there is now a 50-50 chance both Lake Mead and Lake Powell—the Colorado’s major feeders—will be bone dry by 2021. And since the entire area runs on hydroelectric power, the study also found that this energy tap could be turned off by 2017.” <http://ecoearth.com/eco-op-ed/482-steady-state-a-sustainable-economy-for-the-southwest.html>

7. “Colorado River water policy faces an age of limits” *The Salt Lake Tribune*: April 20, 2010
Climate scientists are predicting a 10-to-30 percent reduction in flow for the Colorado—a stark contrast to the rosy assumptions that underlay the Colorado River Compact when it was signed 88 years ago. Researchers from the Scripps Institution of Oceanography recently predicted that Lake Mead and Lake Powell have a 50 percent chance of going dry by 2021. These days, Lake Mead is at 45 percent capacity and Lake Powell is at 57 percent. http://www.sltrib.com/opinion/ci_14921852