



**Second Draft of Possible Recommendations
Water Adaptation Policy Work Group
June 13, 2007**

**~~WA-Introduction
Vulnerability and Risks~~**
[Moved to WA-1]

**WA-1
Need for Leadership**

Initial Drafts by Brad Udall, David Robbins, Marc Waage

The consensus of the scientific community is that warming caused by human emissions of greenhouse gases will have significant effects on water supplies and availability in many parts of the world, including the West. The American Water Works Association, the primary trade group of water management professionals, has written that “global warming is a fact and water managers need to plan accordingly.”

Global warming will likely affect Colorado’s water supplies in several ways.

- **Reduced streamflow.** There is a consensus of model projections that warming will continue in Colorado, leading to more winter precipitation falling as rain and less as snow, lesser snowpack accumulation, earlier runoff, and more evaporation. Most recent models project less or unchanged total precipitation in this region, but there is no clear consensus yet on this point. However, studies do indicate that a substantial increase in precipitation would be needed to offset the reduction in streamflow from more evaporation and plant use from other stream system losses caused by warmer weather. Most water used in Colorado comes from streamflow.
- **More drought.** The frequency, duration, and severity of droughts are projected to increase, further reducing water supplies and making water use restrictions more likely.
- **Earlier snowmelt.** Warmer weather is expected to melt mountain snowpack earlier. An early melt potentially increases evaporative losses, reduces summer streamflow, and disrupts established patterns of the timing of water capture and use under existing water rights.
- **Intense precipitation.** Precipitation is expected to be more concentrated or intense, potentially making the capture and storage of water more difficult. Increases in

flooding are possible, with risks to lives, property, water quality, and the environment.

- **Increased water needs.** The growing season is expected to be longer and warmer. This will increase the water requirements of plants. Irrigation of landscapes account for roughly half of the municipal water use along the urban Front Range. Increases in water use in others sectors, particularly agricultural uses with senior water rights, could reduce the supplies available to municipal providers with more junior water rights. Water use for cooling and other weather dependent uses could increase with temperatures.
- **Degraded water quality.** Water quality is projected to degrade due to reduced streamflow, increases in forest fires and subsequent runoff of sediment, higher stream temperatures, and other factors. This potentially will increase maintenance and treatment costs. Sedimentation in water supply systems is expected to increase and this could decrease water storage capacity and increase maintenance costs.
- **Interstate compact calls.** Reduced streamflow and increased water use could increase the contention over interstate allocations which are based on “normal” precipitation patterns.
- **Secondary impacts.** There are also a number of important secondary impacts which have the potential to affect water management, including more forest fires which can lead to increased runoff causing sedimentation of reservoirs, and forest pest outbreaks which may affect total runoff and runoff timing.

[Mostly new] Several climate change studies have investigated possible effects on future flows of the Colorado River, the state’s largest source of surface water, which is not just used on Colorado’s Western Slope but also is also diverted for use in cities and farms east of the Continental Divide. All studies done to date project that climate changes will lead to Colorado River flows being reduced below those seen in 1905-2000. Recent projections range from a very significant reduction of up to 50% by Hoerling and Eicheid to a modest reduction of a few percentage points to 11% by Christiansen and Lettenmaier. Similar studies have not yet been conducted with respect to other river systems in Colorado.

[All new] Many of these predicted impacts have already been observed across the West and in Colorado.

[All new] These changes are likely to have far-reaching effects in Colorado.

[All new] It will be harder to meet our water needs in the future. Phase 1 of the Colorado Water Conservation Board’s Statewide Water Supply Initiative projected that even with some additional conservation measures there could be a net increase in demand of 630,000 acre-feet of water per year to meet just the municipal and industrial needs of the population projected to live in the state in 2030. In contrast, a team of scientists who used a model of future climate to project the effects of global warming on water supplies in the several western river basins, including the Colorado River basin, concluded:

What this work shows is that, even with a conservative climate model, current demands on water resources in many parts of the West will not be met under plausible future climate conditions, much less the demands of a larger population and a larger economy. Barnett et al, The Effects Of Climate Change Onwater Resources In The West: Introduction And Overview (2004) (emphasis in original).

Water engineering and management will need to change. They have always been based on the idea that the future will look like the past. Reservoir design, flood planning, municipal yield are but three of the critical water management areas where good engineering practice has dictated the use of historical hydrology in planning. As the globe warms, past assumptions about municipal yield, supply, demand, flood control and other water management issues based on historical hydrology will become less valid.

Agriculture consumes a significant majority of the water used in Colorado, so if climate change produces a more restricted water supply over the long term it will have a commensurately greater impact on agricultural production in the state. If water supplies become scarcer, the amount of land in irrigated agriculture inevitably will be reduced. In the event of shortages, there will be a movement of water use from lower intensity uses to higher intensity uses, such as municipal supplies.

[All new] The combination of changes in water availability and the legal regimes governing water uses may affect both individual water users and the state as a whole. Changes in runoff timing could affect whether holders of water rights will continue to be allowed to divert and use water when they need to. State or regional water shortages may trigger the application of interstate compact requirements that could lead to additional water restrictions in Colorado.

[All new] All in all, the likely effects on water supplies represent Colorado's greatest vulnerability to climate change.

Recommendation

1. **[All new]** All federal, state, and local public officials in Colorado who have general responsibilities for the quality of life in the state or particular responsibilities for meeting the water needs of Coloradans should exercise leadership to reduce human contributions to climate change and to prepare for and reduce the ways in which climate change may make it more difficult to meet the state's water needs.
 - A.** The first and most important way to reduce the effects of climate change on our water supplies is to reduce climate change itself, so our public officials should exercise leadership through their direct actions and influence on others to bring about an appropriate level of reduction in emissions, in Colorado and across the nation and world, of climate-changing greenhouse gases.

- B.** Even if greenhouse gas emissions are reduced, however, scientists say that our climate is likely to change enough to have significant adverse effects on Colorado's water supply, and those likely effects pose substantial, far-reaching risks to the quality of life in the state. Accordingly, our public officials should give the highest priority to taking actions, including those identified here, to protect Coloradans from the adverse effects of climate change on our water supplies. These actions should include educating the public about the risks that climate change poses to the state's water supplies.

Key public officials to whom this recommendation apply include our elected representatives to Congress, the Governor and other officials in the executive branch of state government, members of the Colorado General Assembly, elected and appointed officials in local governments, water providers, and officials in public colleges, universities, and research institutions.

WA-2 3

Consideration of Climate Change in Water Decisions

Initial Drafts by Brad Udall and Marc Waage

[Combined with former WA-6]

Recommendations

1. All Colorado water managers should investigate the impacts of climate change on the water supply systems they manage and determine how they will continue to meet future water needs in light of those impacts. In planning changes in future water supply systems and operating current ones, water providers should:
 - A. Not assume the future will necessarily be like the past. Most water supply planning in Colorado is based on the past hydrology of some recent period of 30 to 50 [?] years, covering . New plans should consider both the substantial variations in regional climate now understood to have occurred in the more distant past and the projected effects of climate change on future hydrology. ~~other future scenarios in addition to historical hydrology.~~
 - B. Assess the vulnerability of their supplies and systems to climate change effects.
 - C. Identify and preserve adaptation options.
 - D. Apply risk management and adaptive management.
 - E. Explore phased approaches to adjust with climate changes.
 - F. Consider how to increase water system reliability, diversity and flexibility.

- G. Use “no-regrets” planning – the use of plans that work well under a wide range of future scenarios.
 - H. Create and participate in regional efforts to model and analyze the impacts of climate change.
2. Water suppliers should carefully consider the appropriate roles under a changed climate of:
- A. Reuse.** A reduction in the water available for first use within a municipal system could also reduce water available for reuse including use in water recycling systems, river exchanges and augmentation plans. Municipal water rights that were transferred from very senior agricultural rights may not see a reduction in water available for the first use and reuses. Some municipal water rights cannot be reused. Suppliers should analyze their system vulnerability.
 - B. Conservation.** See recommendation WA-7, below.
 - C. Storage.** The value of new or enlarged storage in reducing the impacts of climate change on municipal water supplies is being debated in the west. Some believe that reduced streamflow would mean there would no longer be additional water available for storage in new or enlarged reservoirs. Others believe new storage could play a role along with other measures to smooth out what could become an even more variable supply. In particular, new or enlarged storage could be important to capture the water from more intense precipitation events.
3. **[All new]** The state government should provide assistance to water providers without the resources needed to consider the effects of climate change on the water supply systems they manage to help them do so.

References

AWWA - Climate Change Primer for Water Providers (2006) and Climate Change Webcast (2007) Stratus Consulting- Climate Change Report for Denver Water. (2006) National Research Council – Colorado River Study (2007) Southwest Hydrology – Inconvenient Hydrology (2007) Water Utility Climate Change Conference, San Francisco (2007) [Need to add exact cites]

[Note: Brad’s original draft recommendations are below]

- 1. ~~Planning for new water projects should use both paleohydrology and climate change hydrology.~~ [See WA-2-1A, above]

2. ~~The state should develop the capacity to generate future and paleo hydrology for all river basins using inputs from multiple climate models and multiple hydrology models. [See WA-5B]~~
3. ~~The state should educate the public about the impacts of climate change on water supplies. [See WA-1B]~~

WA-3 2
Colorado River Water Availability
Initial Draft by Eric Kuhn

The 2007 version of the Colorado Water Conservation Board (CWCB) annual project authorization bill (SB-2007-122) directed the CWCB to evaluate how much remaining Colorado River water the State of Colorado has to develop. Section 15 of that law states:

“(1) In addition to any other appropriation, there is hereby appropriated, out of any moneys in the Colorado water conservation board construction fund not otherwise appropriated, to the department of natural resources, for allocation to the Colorado water conservation board, for the fiscal year beginning July 1, 2007, the sum of five hundred thousand dollars (\$500,000), or so much thereof as may be necessary, for the board to evaluate water availability in the Colorado river basin and its tributaries. The board shall work in full consultation with, and with the active involvement of, the basin roundtables. The study shall consider current and potential future in-basin consumptive and nonconsumptive needs. The board, in consultation with the basin roundtables, shall recommend whether additional study or phases of study should be undertaken.”

This is an essential public policy question. Under 2005 legislation, (HB-2005-1177) the State of Colorado is engaged in a broad public effort to take a comprehensive evaluation of Colorado’s future water needs and identify solutions to meet the identified needs. Through the HB-1177 process and the companion Statewide Water Supply Initiative (SWSI) process, a number of new projects have been proposed in the future. These projects range in size from small local projects to improve water use efficiency to large multi-state, multi-billion dollar projects that would convey water as far away as Flaming Gorge Reservoir to the Colorado Front Range.

Determining now much Colorado River water is available to Colorado under various federal statutes, state statutes, interstate compacts and international treaties (commonly referred to as the “Law of the River”) is going to be a complicated and difficult endeavor. The issue is complicated by the potential impacts of climate change. For decades, Colorado water officials have assumed

that the State of Colorado could develop at least 3.0 million acre feet per year. However, this conclusion is based on the basic assumption that in the future, the Colorado River flows will be similar to the most recent past (1905-2000). Scientific studies, however, project that Colorado River flows will actually be reduced as a consequence of climate change.

Recommendation

1. To ensure that the new Colorado River water supply study is accurate, relevant, widely accepted, and useful for future decision-making, the state government should ensure that the potential effects of climate change are considered in the study.

WA-4

Interstate Compacts

Initial Draft by David Robbins

Interstate compacts to which Colorado is a party apportion among our state and other states the right to make beneficial consumptive use of interstate rivers and related water supplies. Several compacts, including the Republican River Compact and the Rio Grande Compact, contain mechanisms to adjust Colorado's apportionment based on climatic conditions. Others, such as the Colorado River Compact, contain requirements for delivery to downstream states of at least specified minimum amounts of water, causing Colorado to bear a greater share of any significant shortage. In the case of the Colorado River, therefore, the operation of the compact can serve to increase Colorado's vulnerability to climate change-driven water shortages.

Although it is a popular topic of discussion, the idea of renegotiating interstate compacts is not particularly realistic or appealing. All of the signatory states to compacts in the western United States are suffering from varying degrees of water shortage and will be adversely affected by water shortages brought about by climatic change. Each signatory state would have a similar goal in any compact negotiation, namely to acquire a greater share of the available supply for its citizens.

Recommendations

1. Colorado should not assume that interstate compacts can or will be renegotiated to reduce the effects that climate change may have on the amount of water available for use in the state. Planning based upon assumed changes in compacts would likely lead to nothing but frustration and disappointment.
2. **[All new]** The state government should evaluate with respect to each major river basin the combined effect in that basin of the possible effects of climate change on water supplies and the operation of the interstate compact applying to that basin.
3. **[Newly phrased]** The state government should develop for reach major river basin a mechanism [or plan?] to deal with the potential combined effect of climate change-

induced water shortages in that basin and the operation of the interstate compact apportioning water for that basin.

WA-5A
Regional Modeling and Climate Data
[Newly Split]
Initial Draft by Ben Harding

Understanding and adapting to climate change's effects on water supplies will require good information on what changes are occurring, with respect to such key elements as temperatures, snowpack, the timing of snowmelt, and streamflows. The data collection systems that currently exist to gather these information were not designed to track changes in climate, and so are incomplete to meet today's needs. Also, many of the programs for collecting and disseminating these data have deteriorated or have been diverted over the last quarter-century, with the result that many long-term climate and streamflow records have been interrupted.

Recommendations

1. The state government should lead an assessment of the information water users need to plan for adaptation to climate change.
2. The state government and water users should support additional data collection with an emphasis on preserving and extending long-term records.
3. **[All new]** Colorado's representatives in Congress, our state and local governments, and water providers should support the necessary increases in federal funding for collection of key data related to climate change's potential effects on the state's water supplies.
4. *To come: expansion of CWCB's current drought vulnerability assessments*

WA-5B
Regional Modeling and Data
[Newly Split]
Initial Draft by Ben Harding

Climate change will impact water supply by changing the amount and timing of streamflows and the amount and timing of water requirements for agricultural, industrial and municipal uses. A water user requires estimates of future water use to plan its own system and operations, but also to understand how competing water rights will affect its water supply.

The nature of future water supply conditions can be estimated based on projections of future climate conditions from climate models but such estimates require that the models' output be translated into projected streamflows and water requirements at relevant locations. Because

current climate models use large grids (with a typical grid cell covering one-fourth of Colorado), model results must be “downscaled” to a finer level of detail prior to translation to streamflows.

Making estimates of future water supply conditions presents a number of technical challenges:

- **Scale/Translation.** For the reasonable future, climate model data will be available at scales that are far too large for planning and decision making by water users and these results must be translated to streamflows. Downscaling and translation techniques are necessary and these are just becoming available outside the research community.
- **Observed data.** Downscaling and translation require good records of observed climate and streamflow. The programs for collecting and disseminating these data have deteriorated or have been diverted over the last quarter-century, with the result that many long-term climate and streamflow records have been interrupted.
- **Water rights response.** Almost all water supply models in Colorado rely on historical records of water rights yields, calls, or both. Climate-change induced changes in streamflows and water use will affect the yield of individual water rights and the pattern of calls. Historical water rights yields and calls can no longer be depended on to represent future conditions.
- **Uncertainty.** Projections of future climate contain much uncertainty, arising from projections of future policy and economic responses (which are necessary to estimate future greenhouse gas concentrations), and from simulations of future climate responses. Further uncertainty is introduced by downscaling and translation methods.

Collecting the data and constructing and running the models necessary to project future streamflows is a substantial effort. Many smaller municipalities and most individual agricultural users will not have the resources to make these assessments. Further, virtually every productive watershed in the State is shared by many water users, so if water users made independent assessments, the result will be much duplication of effort.

[All new] Several scientific studies have used climate models to make projections of climate change’s possible effects on water supplies in the Colorado River basins, but the state’s other river basins have not been studied in the same way.[What should be said about efforts by others, e.g, Denver Water and/or other water providers, to use climate models to project future water supply effects?]

Recommendations

1. The state government, water providers, and others should cooperate in:

- A. **[All new]** Developing information from climate models on the possible effects of climate change on water supplies in each of the state’s major river basins. The state government should not impose common planning assumptions on water providers, nor indirectly determine common assumptions by embedding them in information on models and data supplied to water providers.
- B. Developing common practical tools and databases for downscaling and translation of climate model outputs. These tools should allow for the flexibility, on the part of water providers, to choose from a variety of approaches to assessing climate change effects.
- C. Setting up and maintaining a “live” [?] clearinghouse of ~~GCM~~ climate projection data.
- D. Supporting cooperative efforts among ~~users~~ providers to make basin-wide assessments of water rights yields and call patterns in support of the individual water supply modeling of water ~~users~~ providers.
- E. ~~The state government should not impose common planning assumptions on water providers.~~ [See recommendation #3, above.]

WA-6
Planning and Operating Water Supply Systems
 Initial Draft by Marc Waage

[Combined with WA-1]

WA-7
Water Conservation

[submitted by Bart Miller, Andy Colosimo and Marc Waage¹, June 2007]

Decreasing river flows and lake and reservoir levels that are the expected by-product of climate change provide great incentives to step-up water conservation throughout Colorado.

Role of State. While the bulk of conservation work needs to be carried out by individual water providers and water users throughout Colorado, state agencies can play an important role by providing funding and technical assistance and helping shape regional and state-wide education and message development.

¹ This version is Bart’s best effort to merge prior drafts with elements that both Marc and Andy like.

Planning. Recent additions to state law require more frequent conservation planning and conservation goal-setting by water suppliers. Substantial state funding is available in the form of planning and implementation grants from the Colorado Water Conservation Board.

Water Supplier Dilemma. Water conservation is favored by many water suppliers as a cost-effective means to decrease the need for new water development. The risk of a drying climate poses a new dilemma for water suppliers. Do the suppliers use the water saved from conservation to: (1) supply new population growth, (2) reserve some or all of the saving to protect against shrinking supplies; or (3) set aside some savings for environmental purposes such as improving river habitat. If the supplier uses the savings exclusively to supply growth in their service area, water efficiency is increased but more people become dependent on the same supply of water. If that supply shrinks, the additional savings needed to provide for the essential human uses in that supplier's service area might affect landscapes and businesses within the service area. Water suppliers need to recognize that the choices are very case-specific and should carefully consider the risks and potential tradeoffs.

Recommendations:

1. Many cities across the state have demand management programs but, in many areas, improvements can still be made as cities refine their conservation programs and savings goals. ["Cities should ..."?]
2. Water providers are strongly encouraged to ["should"?] implement and maintain strong and diversified water conservation programs. These programs should consider measures that are cost-effective for both the utility and customers and that accomplish significant water savings. Conservation programs should address all customer segments, particularly those that demand the greatest volume of water or place the greatest burden on the water system in terms of peak use. Regulatory and voluntary measures are necessary and each should be evaluated and utilized to address different aspects of both indoor and outdoor water use.
3. Water providers should evaluate the actual impacts of conservation on system yields and reliability through model runs and reasonable assumptions about technological and behavior savings that may be expected from customers before and after the implementation of conservation measures. Mechanisms must be devised and applied to effectively and accurately monitor and report program savings in order to evaluate this impact.
4. Specific recommendations for demand-side programs and measures include: ["A or B should ..."?]
 - A. Rate structures that reward conservation and provide incentive to avoid water waste.

- B. Rebate programs that encourage customers (both residential and business) to install high efficiency water fixtures (e.g., toilets and clothes washers).
 - C. City ordinances and utility programs that encourage efficient irrigation.
 - D. Business and residential audits that identify property-specific water issues and educate the customer on how to curb demand.
 - E. Education programs that deliver a consistent conservation message to all.
 - F. Water loss reduction programs that decrease treatment costs and plant capacity needs.
 - G. Using non-potable water supplies for landscape or other appropriate water use whenever possible and metering this use, just as is done for treated water.
5. **Outdoor Water Use.** As municipal landscapes’ irrigation accounts for roughly half of total annual municipal water use, it deserves special attention. [“A or B should”?] Successful outdoor programs include:
- A. Incentives and requirements to amend the soil before planting new landscapes.
 - B. Encouraging Xeriscape—to boost the prevalence of water-saving landscapes. For new development, consider limiting the amount of turf as a percentage of total landscaped area. For existing development consider turf removal incentives for both residential and commercial customers. Landscape changes may lower owner's maintenance costs.
 - C. Increasing efficiency by changing watering habits (decreasing the numbers of watering days per week and lowering the amount of time per sprinkler zone).
 - D. Irrigation improvements, including rains sensors (that turn off sprinkler systems during rain) and more efficient sprinkler head placement and water pressure.
6. **Looking Forward.** Because Colorado’s new residents have not yet arrived, there can and should be a special focus on new development to decrease the future water-use footprint. [“A or B should”?] This involves encouraging residential and commercial developers and builders to use state-of-the-art conservation practices.

References:

American WaterWorks Association, "*Water Resources Planning (M50), Second Edition,*" 2007.

Colorado Foundation for Water Education, "Citizen's Guide to Colorado Water Conservation," 2004.

Metro Mayors Caucus and Colorado WaterWise Council, "Best Management Practices for Water Conservation and Stewardship," 2005; found at www.coloradowaterwise.org

Pacific Institute, “Waste Not, Want Not: the Potential for Urban Water Conservation in California,” 2003.

**WA-8
Agriculture**

[Moved to Introduction]

**WA-9
Energy and Water**

Two drafts were submitted

Draft #1 by Andy Colosimo

Hydropower is a proven technology that by improving efficiency of existing plants or taking advantage of existing water storage and conveyance facilities can provide additional generation with little or no negative environmental impacts.

Colorado's geography provides for a unique synergy between water providers and energy generation through the use of hydroelectric power. Communities especially front-range water providers have ideal attributes for development of small hydroelectric projects – significant volumes of water flowing from higher elevations to water treatment facilities at lower elevations.

Successful small hydropower projects require adequate flow rate and water pressure, reasonable physical access for construction and maintenance, access to transmission lines and ability to secure a FERC license or exemption.

Climate change or drought conditions could pose challenges to hydropower generation located in snowmelt dominated basins. A decrease in water supply could limit power generation opportunities.

Another relationship also exists between water and power and that may be impacted from higher temperatures. Power generation is highly dependent upon water for cooling use – increased temperatures may place additional demands on water resources to cool the plants.

Recommendations

1. Additional hydropower opportunities should be evaluated and encouraged while recognizing the costs and risks associated with additional units.
2. Cooling technologies should be evaluated on all new electricity generating facilities.

Draft #2 by Brad Udall

Water and Energy are inextricably linked. In the case of drinking water, drinking water treatment, distribution, and waste water treatment all require energy. Heated water also requires energy, typically electricity or natural gas. In most cases this energy comes from fossil fuels which result in carbon dioxide emissions. Conserving water therefore not only saves water, but it also saves energy and may reduce carbon dioxide emissions.

On the other hand, there is no power without water: water is used for cooling, for hydropower. (See Andy's stuff).

Colorado's geography means that most established water distribution is accomplished using gravity. However, some pumping does occur and at eight pounds per gallon pumping costs can be significant sources of carbon dioxide if conventional energy is used.

New water projects in Colorado frequently involve moving water over significant distances because of the scarcity of undeveloped water near population centers. Unallocated water is usually far downstream or even across mountain ranges from the anticipated point of use. In these cases Colorado's geography may impose potentially significant pumping requirements. If the energy for these projects comes fossil fuels, significant carbon dioxide may be emitted.

Recommendations

1. Link between water conservation, energy conservation and carbon dioxide must made visible.
2. New water projects must explicitly consider carbon dioxide emissions.

WA-10 **Information Exchanges** Initial Draft by Ben Harding

Climate change presents complex policy, planning and operational issues to water users, water managers and appointed and elected officials. Planning for adaptation requires an understanding of the potential impacts of climate change, of the probabilities that particular impacts will occur and of the range of potential technical and policy responses to those impacts. While there is no shortage of information about climate change, much of that information exists at two extremes: academic journal articles, research reports and policy analyses; or articles in the popular press (not to mention the entertainment industry). It is difficult and inefficient for water resource managers to use the academic resources, but the value of the information in the popular press is dubious.

Likewise, the sophistication of water-dependant organizations in Colorado covers a very wide range. Large organizations, such as large utilities or large water conservancy districts, have their own technical staff, while a small town or a small mutual ditch might have only a part-time manager or maintenance person.

For these reasons it will be difficult to convey information about climate change to the broad spectrum of water users throughout the state. But, on the other hand, Colorado is blessed with exceptional technical, research and educational resources in the fields of climate, water resources and policy.

Recommendations

1. Support the development of at least one journal, using either traditional or electronic media, that addresses an audience of water resources professionals, managers and policy makers. Such a journal should translate research products to useful practice- and policy-oriented information. In order to be authoritative, such a journal will need some degree of peer review.
2. Support efforts, by state universities, state and federal agencies, and other organizations, to:
 - Provide practice-oriented information about climate change;
 - Host information exchanges among water management organizations, at both the policy and technical level, where they can trade experiences, successes and failures;
 - Conduct research oriented toward practical issues of water resources management and policy in the face of climate change; and
 - Provide opportunities for training and education in specific, practice-oriented topics related to climate change.
3. Encourage and facilitate cooperative working relationships among water-provider organizations in order to facilitate joint adaptive responses.
4. Develop training and education opportunities for elected officials.
5. *To come: recommendations with respect to Water Availability Task Force and Western Water Assessment*

WA-11

Recreation, Tourism, and Environment

Initial Draft by Bart Miller, Chris Crosby

[Environment combined with water quality, WA-12]

Climate change's effects on Colorado's snow and water resources are likely to have a wide range of impacts on the opportunities for recreation and tourism in the state and the industries that support them. These impacts threaten to decrease the intrinsic and economic value of resources that currently bring enjoyment to millions of residents and add billions of dollars to the State's economy.

Several recreational and tourism impacts include:

- **Fishing.** Warmer trout streams will eliminate or reduce trout populations in many river reaches. Lower flows will make trout more susceptible to disease, winter kill, and angling pressure. Angling and related activities are estimated to bring hundreds of millions of dollars annually to Colorado's economy.
- **Skiing.** Less snow and warmer temperatures means shorter ski seasons and fewer days of champagne powder. Increased snow-making will reduce stream flows farther, potentially affecting angling and increasing pollutant concentrations that are harmful to aquatic life.
- **Rafting and Boating.** Less runoff will shorten the prime spring runoff and affect river running (rafting was estimated to have \$135 million in economic benefit in 2006). Many lakes and reservoirs are likely to have decreased levels, affecting marinas and exposing sand and dirt to wind, snow, and erosion.
- **Hunting.** Fewer wetlands will leave fewer nesting ponds for ducks and geese and few hunting spots in the fall. Vegetation changes may affect elk and deer food supply at different elevations.
- **Camping, Hiking, and Biking.** More forest fires will mean more forest closures and campfire restrictions. The aesthetic value of streams will decrease as flows drop.

~~*Ironically, tourism itself is partially responsible for the reduction in recreational quality and quantity because it increases impacts to outdoor resources by tourists themselves and the increase in residents who move to Colorado after a visit as a tourist. In the face of increasing demands on a limited supply of water, it's necessary to re-think some of our sacred cows, such as the assumption that population growth in Colorado can continue indefinitely. [Population growth is a much larger issue about, and driver of, climate change than just with respect to recreation and tourism. Whatever is said about population growth should be in a more appropriate place, I think. – Stephen]*~~

Recommendations

1. State and federal agencies should undertake studies to evaluate possible impacts of climate change on recreation and tourism in Colorado, ~~and the environment.~~ Responsible

state agencies include the Division of Wildlife (DOW), Colorado State Parks, Water Quality Control Division, Air Pollution Commission, as well as the state legislature [legislature? – Stephen . Responsible federal agencies include the Forest Service, Bureau of Land Management, Fish and Wildlife Service, Corps of Engineers, Department of Agriculture, and Environmental Protection Agency. [Federal studies specific to Colorado? -- Stephen]

2. The potential impact of climate change on the ~~value of~~ outdoor recreation and tourism ~~the environment~~ underscores how essential it is for natural resource management agencies to set the example in decreasing greenhouse gas emissions while at the same time preparing for impacts on Colorado's valuable waterways. Federal, State, and local management agencies should increase funding for programs that lower greenhouse gases. For example, Rocky Mountain National Park can help decrease car user miles (and congestion) by increasing bus schedules, especially during the busy summer season.

OR, an alternative suggested by Stephen: Government agencies and businesses managing and providing outdoor recreation and tourism opportunities and services should take visible actions to reduce their emissions of climate change and to adapt to the effects of climate change, and educate the public on the risks of climate change and actions that can be taken to reduce it and respond to it.

3. **[Newly phrased]** The Colorado Water Conservation Board should ~~accelerate its instream flow program to secure water flows and enforce its existing water rights against injury by other water users.~~ evaluate its instream flow program for any changes needed in its administration to reflect the effects of climate change on the purposes for which the program was established.
4. **[All new]** The state government should investigate habitat protection and enhancement needs for terrestrial and aquatic species particularly vulnerable to climate change.

References

Todd Pickton and Linda Sikorowski, "The Economic Impacts of Hunting, Fishing, and Wildlife Watching in Colorado"; found at <http://wildlife.state.co.us/About/Reports/EconomicImpacts/>

Colorado River Outfitters Association, "Commercial River Use in Colorado: 2006 Year End Report"; found at <http://www.croa.org/media.htm>

WA-12 Water Quality and the Environment Initial Draft by Mark Pifer

[Note: Stephen suggests that this be further expanded to also deal appropriately with other water-related environmental effects of climate change besides water quality effects.]

Climate change can have significant impacts on the water quality of our rivers and lakes and the associated aquatic ecosystems. Climate driven increases in water temperature, seasonal decreases in flow, and changes in the intensity and duration of precipitation events can all influence water quality standards and designated beneficial uses. Potential impacts include:

- Increased pollutant runoff from more frequent and severe rainfall events.
- Periodic drought related low flows below aquatic life needs.
- Loss of anticipated dilution flows.
- Channel reconfiguration and sediment transport through flooding.
- Reduced dissolved oxygen levels in waterbodies.
- A loss of, or change in, biodiversity.
- An increase in forest fires and accompanying run-off concerns.
- [Moved from WA-11] Threatened and endangered species, including four fish species native to the Colorado River and its main tributaries, will face additional pressure due to changes in stream flows, increases in water temperature, and degradation of other habitat elements.

Climate induced hydrologic modifications may similarly affect the implementation of water quality regulatory programs, such as compliance with wet weather mandates. (combined sewer overflow (CSO) and stormwater BMP's); the establishment of permit effluent limitations based on "low flow" averages; and the listing of waterbodies as impaired under Section 303(d) of the Clean Water Act (TMDL program) due to increased pollutant loadings, elevated temperature or the mere loss of flows. Water resource allocation decisions designed to adapt to changes in water availability will also hold implications for water quality. For example, there may be a tendency to expand reuse programs, necessitating additional protective reuse regulations, or to adopt enhanced treatment techniques, such as reverse osmosis, with attendant brine disposal concerns.

Recommendation

1. Additional data gathering and research on water quality impacts related to climate change, along with a re-examination of certain regulatory programs under both the Clean Water Act and the Safe Drinking Water Act, are warranted. EPA and certain states have commenced an examination of these issues and their efforts should be utilized in the development of a response strategy.

References

EPA Website on Climate Change: <http://www.epa.gov/climatechange/>

Memorandum from Benjamin Grumbles, EPA Assistant Administrator for Water, to office Directors on Climate Change and the National Water Program, dated March 2, 2007.

Climate Change Science Program Synthesis and Assessment Product 4.4, Preliminary Review of Adaption Options for Climate Sensitive Eco-Systems and Resources (EPA et. al., to be completed December, 2007)

WA-13 Groundwater

Initial Draft by David Robbins

The tributary groundwater supplies in the State will respond to the effects of climate change in a manner very similar to that of the surface stream systems to which they are connected. As the surface stream flows diminish their ability to replenish groundwater systems declines commensurately; as surface irrigation supplies diminish the ability of those irrigation systems to recharge the groundwater declines; and as “conservation” and improved efficiency in agricultural irrigation practices increase in response to climate change there is a resulting loss in return flows to the groundwater systems.

Nontributary groundwater systems, such as the Denver Basin, are relatively immune to the effects of climate change. On the other hand, they are effectively non-replenishing from natural sources and as tributary systems are affected by climate change, the temptation to continue to rely upon them and mine the water within them will increase hastening their ultimate elimination as viable source of water supply.

Recommendations

1. Colorado should reduce the use of groundwater for irrigation supplies in groundwater-dependent basins including the South Platte, the Republican, the Arkansas and the Rio Grande until recharges match discharges from pumping, natural losses and the obligations to neighboring states under our compacts.

WA-14 Colorado Water Institute [To come]

See the following information about the Arizona Water Institute and the Colorado Water Resources Research Institute:

[Arizona Water Institute:](#)

Introduction

Arizona is known worldwide for its innovative water management activities. Although the water issues facing the state are daunting, the state's commitment to long-term water supply availability has resulted in billions of dollars of investment in renewable supplies, innovative regulatory programs, and significant institutional capacity.

The Arizona Water Institute (AWI) combines the expertise of Arizona's water managers with the resources of the three universities, to support water resources management and technology development in real-world applications. This unique partnership - which also includes the Arizona Department of Commerce (ADoC), Arizona Department of Water Resources (ADWR), and Arizona Department of Environmental Quality (ADEQ) - was formed to provide access to hydrologic information, support communities, and develop technologies to promote water sustainability.

Structure

The Arizona Water Institute connects the three universities, three state agencies, and Arizona communities. Direction is provided by an Executive Committee comprised of:

- the Vice-Presidents for Research at the three universities,
- the Chief of Staff of the governor's office,
- the chair of a 38 member external advisory board, made up of diverse water interests
- the Director of the Department of Water Resources (a rotating position among the three state agencies)

The committee provides oversight for the Executive Director and all AWI activities. Faculty coordinators on each campus help match resources within the three institutions to relevant AWI projects and ensure the timely completion of projects. Associate Directors located in the Arizona departments of Water Resources, Environmental Quality, and Commerce ensure that the agencies are given timely and appropriate support by AWI by working on projects and providing technical assistance.

AWI Mission:

- Serve as the hub of research, community assistance and analytical support to give Arizona the tools to assure clean and sustainable water resources for the next century and beyond;
- Provide education, training, and professional capacity building to the public, state, local and tribal government decision-makers, water professionals, industry, and others about using, conserving and managing water in arid/semi-arid environments;
- Create water-management expertise and technologies that produce new products and services for Arizona companies to export worldwide, thus creating a major new economic development driver for Arizona.

The AWI will also enhance the universities' abilities to attract top students and faculty from around the world by providing a mechanism through which collaborative and innovative multi-disciplinary water curricula will be offered.

Challenges and Focus

Arizona's water challenges are similar to those faced in arid environments around the world: sustainability in the face of drought and continued population growth; water quality, safety and security; inadequate hydrologic and planning information; maintaining healthy ecosystems and watersheds; and providing high quality supplies and treatment systems to sustain high technology industries. The solutions to these issues combine social, natural and physical science, including a focus on water policy, water management and law, as well as developing new data, tools and techniques for decision-makers.

Developing sound water policy requires both excellent science and careful consideration of the complexities of the natural, economic, political, social and legal forces that affect water availability and use. This information must then be incorporated into the decision-making processes of governments, water practitioners and businesses. AWI will provide the bridge between science and policy decisions by working with the private sector, federal government and public partners to:

1. Support the development of sound water management and conservation practices for Arizona and other water challenged regions through improved access to water-related information and expertise:
 - o Create a water sustainability decision support system for water professionals and policy makers, combining data bases, web access to maps, trend analysis, data products, scenarios and forecasts linked to models with easy user interfaces.

- Develop communication tools to translate scientific knowledge into useful information for resource management and policy.
 - Enhance access to information for stakeholders, including decision-makers, rural watershed groups, Native Americans, cross-border interests and non-English speakers.
 - Establish an information clearinghouse to support conservation efforts.
 - Assist Arizona's regional watershed alliances with fundamental information needs pertaining to hydrology and water resource availability, ecosystem needs, water quality and water management.
 - Raise water literacy of K-12 and higher education students, businesses, government officials, water professionals and the general public through education, research and outreach programs.
 - Respond to key scientific and technology issues and questions raised by stakeholders, decision makers and others through applied research and outreach programs.
2. Evaluate new legal, economic and policy options to expand water supply availability in Arizona and other arid and semi-arid environments:
- Evaluate cost-effective water conservation measures and enhanced architectural design and site planning concepts.
 - Identify and evaluate alternative water management policies and approaches that enhance sustainability in urban, rural and natural ecosystem environments.
 - Evaluate options and assist in implementation of drought planning, water resource regulation, adaptation and response activities.
 - Facilitate convening of water interests to resolve conflicts and encourage the use of scientific information in decision-making.
3. Reduce vulnerability of water supplies in arid and semi-arid environments related to natural hazards, climate variability and change by improving predictions of climate conditions. Improved climatic modeling and forecasting will improve the ability to predict and mitigate against adverse impacts to public health and the environment, as well as vulnerable sectors such as agriculture, forestry and land managers, and the recreation and semi-conductor industries.
4. Encourage development of water sustainability industries and jobs in Arizona through the creation of new technologies, products and services that can be exported worldwide:
- Work with K-12, community colleges and industry to provide education programs that ensure a skilled water workforce
 - Develop new techniques for testing and improving potable water quality, including real time monitoring of biological and chemical contaminants and water purification at multiple scales to assist water providers in ensuring high quality, safe water supplies.
 - Develop enhanced water purification, recycling, and wastewater treatment techniques for municipal and industrial applications, including enhanced opportunities for effluent use in all sectors.
 - Develop water conservation and treatment technologies for specific applications in sectors such as agriculture (hydroponics, bioengineering, use of saline and brackish waters, etc.).

[Colorado Water Resources Research Institute:](#)

The Colorado Water Resources Research Institute (CWRI), an affiliate of [Colorado State University](#), exists for the express purpose of focusing the water expertise of higher education on the evolving water concerns and problems being faced by Colorado citizens.

In 1964, Congress authorized the establishment of a water resources research institute in each state. The Colorado Institute was organized in 1965. In 1981, the Colorado Legislature defined CWRI as we know it today - a statewide institute with the purpose of "developing, implementing, and coordinating water and water-related research programs in the state, and transferring the results of research to potential users."

Through FY1995, CWRRI operated a research program whereby seed grants were made available to faculty to initiate research on water concerns or problems. Recent research projects covered such topics as ground water/surface water interactions, drought management, revegetation after water transfers, non-point source pollution control, and water transfer issues.

Beginning in FY1996 and continuing through FY1998, Congress changed the allocation of funds to the state water institutes. Each institute now receives a base grant of \$20,000 with remaining funds competitively awarded based on regional program priorities approved by the U.S. Geological Survey. Nationally, the program was divided into four regions for the competitive grants: The West, North Central, Northeast, and the Southeast and Islands. Each region receives approximately \$800,000 for research grants. The states included with Colorado in the Western Region are Alaska, Arizona, California, Idaho, Nevada, New Mexico, Oklahoma, Oregon, Texas, Utah, Washington State and Wyoming. In FY1999, each institute received a base grant of \$68,178, restoring a small research grant program.

Today, CWRRI develops partnerships between university water expertise and Colorado water managers to address emerging water problems.

CWRRI publishes research completion reports and conference proceedings in order to make current water knowledge readily available. Informational reports are also prepared to explain water issues to Colorado citizens.