Western water resources in a changing climate

Testimony before the U.S. Senate Committee on Energy and Natural Resources, Subcommittee on Water and Power

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Introduction

In most river basins of the West, especially in California, Oregon, and western Washington, snow (rather than man-made reservoirs) is the largest component of water storage. Most precipitation falls in the winter but about 70% of annual flow is snowmelt; snow provides a roughly half-year delay in runoff. Furthermore, a significant portion of the mountainous West receives much of its annual precipitation as warm snow, with temperatures above -3°C (Bales et al. 2006). Hence, the West is (to varying degrees) vulnerable to climatic variations and changes that influence snowpack. This document updates the testimony I gave to the U.S. Senate Committee on Commerce, Science, and Transportation (Mote 2004).

Observed changes

What changes have been observed in the West since the mid-20th century?

1) The West has warmed by roughly 0.8°C in the November-March season (Mote et al. 2005).

2) Snowfall has diminished at most weather stations; these changes are large and statistically significant in California, Oregon, and Washington (Knowles et al. 2005).

3) Spring snowpack has declined at roughly 75% of sites and the magnitude of declines is largest at low elevations (Mote et al. 2005).

4) Spring snowmelt is generally occurring earlier, roughly 2 weeks (Stewart et al. 2005) and these shifts are larger at lower elevations than at higher elevations (Regonda et al. 2005).

5) In most snowmelt-dominated basins, winter flows have increased and late spring-early summer flows have decreased as flows shift (Stewart et al. 2005).

6) The timing of biological events like flowering of lilacs have also shifted in response to springtime warming (Cayan et al. 2001).

7) Flood risk appears to have changed in many river basins, decreasing in snow-dominant basins and increasing in those with some snow storage.

In several of these studies, a clear quantitative link was established between the observed change and temperature in winter or spring. The warming in the West can now confidently be attributed to rising greenhouse gases and are not explained by any combination of natural factors (Stott 2003).

These hydrologic shifts in response to warming – elevation-dependent losses in snow storage, with concomitant increases in winter flow and decreases in summer flow – are a harbinger of changes to come.

Predicted future changes

The starting point for future changes are the physically consistent global simulations of climate from climate models (e.g., IPCC 2007 Chapters 8, 10, and 11). Such projections typically are reported as seasonally averaged changes in temperature and precipitation (see Figure below, for the A1B socioeconomic scenario). Modeling centers around the world have contributed hundreds of climate simulations to a database maintained by the Program for Climate Model Diagnostics and Intercomparison at the Lawrence Livermore National Laboratory. From such simulations one can construct average changes or produce also a range of changes. The projected warming in North America is greatest in high latitudes in winter, but is greatest in midlatitudes in summer owing partly to a soil moisture feedback. For much of the Lower 48 states, warming is projected to be roughly 0.3°C/decade for winter and 0.4°C/decade in summer for the A1B scenario. Precipitation changes globally tend to be positive in the tropical rainy belt and also in high latitudes, and negative in low latitudes. For North America, models are divided over whether precipitation will increase or decrease for a swath (white area in the bottom row of the Figure) of the Lower 48, but tend to agree on increases in the northern tier of states and tend to agree also that precipitation in the Southwest will decrease.

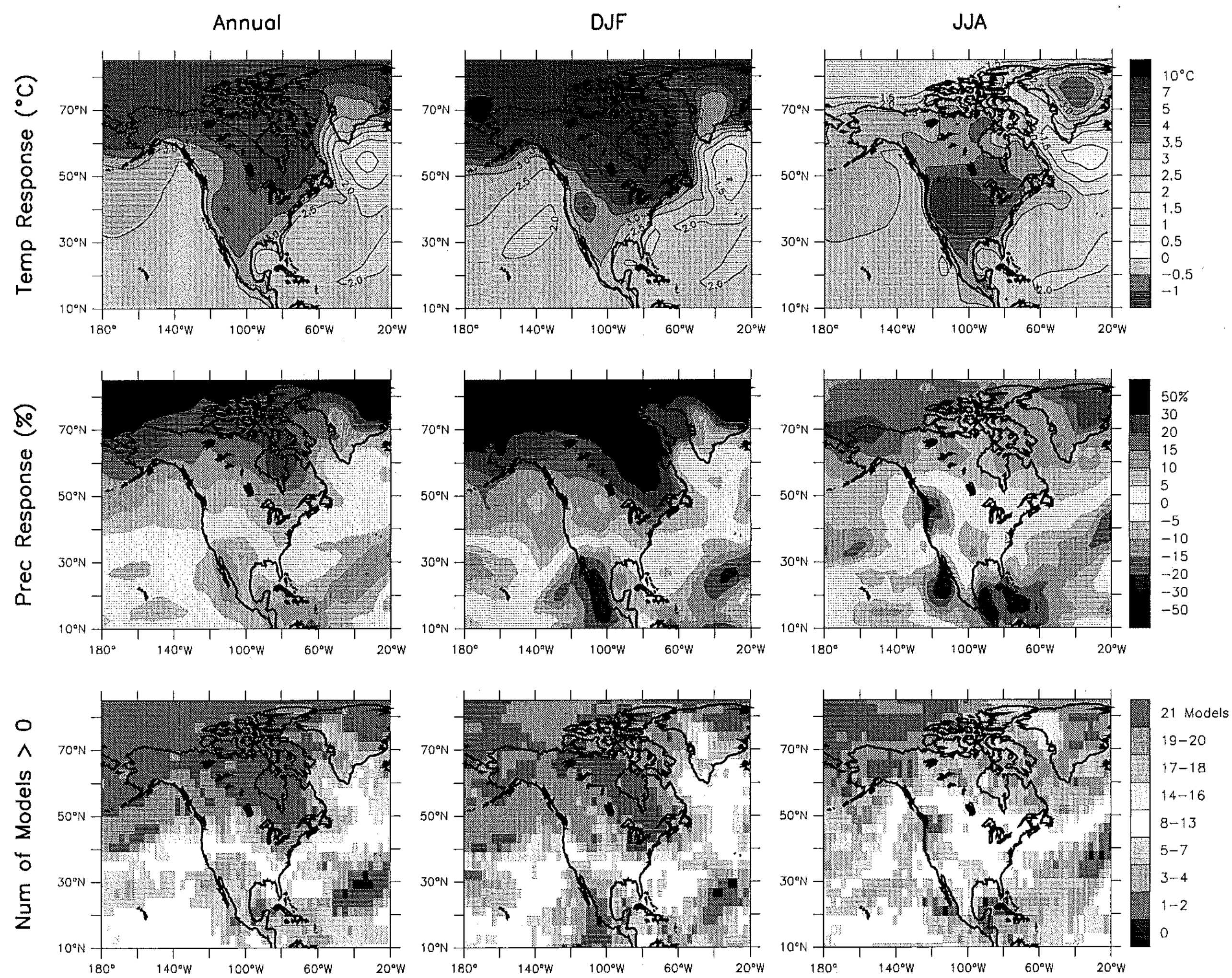

Figure *. Temperature and precipitation changes over North America from the MMD-A1B simulations. Top row: Annual mean, DJF and JJA temperature change between 1980 to 1999 and 2080 to 2099, averaged over 21 models. Middle row: same as top, but for fractional change in precipitation. Bottom row: number of models out of 21 that project increases in precipitation.*

From IPCC 2007, Figure 11.12

Physically-based models of hydrology can be used to translate such changes in climate into future changes in snowpack, soil moisture, streamflow, and so forth. Studies with such models are still relatively new, but it is clear that projected future hydrologic changes (e.g., Payne et al. 2004 for the Columbia River Basin, Christensen et al. 2004 for the Colorado, Maurer and Duffy for California) produce the same types of changes in snowmelt-driven basins as have been observed. For low-end scenarios of future temperature change, the reductions in summer flow, shifts in timing of spring snowmelt, and increases in winter flow over coming decades would be as large as those observed in recent decades, whereas for high-end scenarios of future temperature change the projected hydrologic changes are extremely large.

Management and policy implications

Few water management agencies have begun to explore what these changes would mean for their ability to meet management objectives, let alone proactively address the changes. Some academic studies (e.g., Payne et al. 2004) have attempted to estimate changes in reliability of various water supply systems, and to explore adaptation options.

Federal policy responses could include:

a) directing federal agencies involved in water management to study future streamflow

b) ensuring that existing observation networks (e.g., the USGS stream gauge network and the National Weather Service cooperative network) do not suffer further neglect and decline but instead are upgraded to effectively monitor changes

c) catalyze river basin-scale policy planning, using reservoir optimization models that optimally balance management objectives.

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WRITTEN TESTIMONY OF
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HEARING ON IMPACTS OF CLIMATE CHANGE ON WATER SUPPLY AND AVAILABILITY IN THE UNITED STATES

BEFORE THE
SUBCOMMITTEE ON WATER AND POWER
COMMITTEE ON ENERGY AND NATURAL RESOURCES
U.S. SENATE

JUNE 6, 2007

Chairwoman Cantwell, Ranking Member Corker, my cousin Senator Smith, and other Members of the Committee, thank you for the opportunity to speak with you today on the impacts of climate change on water supply and availability in the United States.

My name is Brad Udall. I am the Director of the Western Water Assessment, an interdisciplinary Regional Integrated Science and Assessment (RISA) project funded by the NOAA Climate Program Office and a joint effort of the NOAA Earth System Research Laboratory and the University of Colorado. The eight RISAs around the country are innovative programs designed to connect climate science with decision makers. There are no other programs anywhere like these, and we are on the front line of dealing with requests for regional information on all aspects of climate variability and change.

Although I was invited to sit on a panel with scientists, I am not a scientist. I am an engineer by training and I have an MBA. During the last four years of my life I have been embedded with scientists at the largest NOAA laboratory in the country where I have had the opportunity to learn about climate from scientists while providing them with a real world view of water management. It has been a fabulous and life changing experience. Formerly, I was a principal at a consulting engineer firm. In preparing this testimony I talked to scientists, water managers, and consulting engineers. Many were eager to share their thoughts on this important topic.

All water planning is based on the idea of a static climate. Normal engineering practice for designing water supply and flood control projects is to plan as if the future will look like the past. However, we now know that our future climate will not look like the past, and that in addition to warmer temperatures the normal patterns of water movement around the globe will change. This is because the water cycle redistributes heat from the equator to the poles-- and it is this movement of heat and water that determines our weather and climate. As the planet warms, these relationships will change, and the water cycle will adjust with potentially large impacts on humans.

This fundamental fact has profound implications for water management. The novelist T. Morris Longstreth once wrote, "Of course we weren't lost. We were merely where we shouldn't have been without knowing where that was." This is the position water managers find themselves in today. As we move forward, all water management actions based on "normal" as defined by the twentieth century will increasingly turn out to be bad bets.

I would like to discuss three issues concerning adaptation to climate variability and change today. The first is the serious situation due to drought and increasing demands that has developed on the Colorado River which climate change threatens to make far worse. The second is my concern about how our national climate change scientific enterprise is being managed, and the third is the need to devote more scientific resources to meeting the needs of decision makers, almost all of whom have a regional or local focus.

The Situation on the Colorado River

Please indulge me in a small bit of family history. My great-great grandfather John D. Lee was asked by Brigham Young to found what is now called Lee's Ferry, the all-important dividing line on the Colorado River between the Upper Basin and the Lower Basin in the 1922 Colorado River Compact. My great-grandfather and my grandfather farmed on the banks of the Little Colorado River in northeastern Arizona. My father, Morris Udall, was part of the Arizona delegation that passed the Central Arizona Project Act in 1968 which now moves large quantities of Colorado River water over 300 miles and 3000 vertical feet to Phoenix and Tucson. And during the course of my life I have been both a Grand Canyon River Guide and a water engineer.

I care deeply about this river which affects 30 million people in seven states and faces an uncertain future even without climate change. The population of the American Southwest is the fastest growing of anywhere in the nation. The recent drought, which has featured extended low flows not seen in the 100-year gauged record, has resulted in the loss 30 million acre-feet of water, the equivalent of two years of annual flow and half of the maximum total storage. The two largest reservoirs, Lakes Mead and Powell, are now approximately half full. Lake Mead is currently losing 1.4 million acre-feet per year, and contains only 10 years of water at this rate of loss[1] because the Lower Basin states have grown accustomed to using excess water from the Upper Basin, water that may not be there in the future under either climate variability or under climate change. According to Reclamation modeling, even under average historical hydrology Lake Mead never refills and Lake Powell takes decades to refill.

With climate change the picture is even more troubling. The West in general is experiencing warmer springs, reduced snowpack, and earlier runoff[2]. The Colorado River basin has warmed approximately 2°F since 1976[3]. Recent studies on the Colorado River indicate that the basin is

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[1] With Lake Powell at about 50% of capacity, current operating practice is to release 8.23 million acre-feet (maf) to Lake Mead which combines with approximately 750,000 acre-feet of tributary inflow to make total annual inflow to Mead of 9.0 maf. Annual releases from Lake Mead total 10.4 maf: 7.5 maf total to Arizona, California and Nevada, 1.5 maf to Mexico to meet our treaty requirements and an additional 1.4 maf in evaporation and other losses.

[2] For an overview of climate related impacts see: "Climatic and Hydrologic Trends in the Western U.S.: A Review of Recent Peer-Reviewed Research" available at:
http://wwa.colorado.edu/products/forecasts_and_outlooks/intermountain_west_climate_summary/articles/wwa_jan_2007_feature.pdf

[3] National Research Council (NRC) 2007. Colorado River basin Water Management – Evaluating and Adjusting to Hydroclimatic Variability. The National Academies Press, Page 61.

likely to have less streamflow in the future[4]. In fact, all climate change studies on the river, some dating back to 1979, have found that less runoff will occur in the future under warmer conditions with either the same or less precipitation, the most likely future according to climate models. A variety of new studies[5] based on the most recent Intergovernmental Panel of Climate Change (IPCC) modeling also paint a future with less water in the basin. Two other second order effects of rising temperatures associated with climate change potentially influence water supply. Insect pests such as the pine beetle are projected to increase, which will affect forest health and the potential for fire[6]. Large forest fires have increased in recent years[7] which may lead to increased reservoir sedimentation and water quality degradation. While these studies and projections may be wrong, the collective picture is troubling and it would be foolish to ignore them.

While the Lower Basin states of California, Arizona, and Nevada have over-consumption and growth problems, the Upper Basin states have another set of problems relating to the uncertainty of their compact entitlements. In the state of Colorado, for example, there is no unappropriated water in any basin other than the Colorado River, but use of Colorado River water is constrained by a 1922 Colorado River Compact downstream delivery requirement at Lee's Ferry. Developing additional water to meet Colorado's needs is now highly uncertain – there could be anywhere from 0 to 800,000 acre-feet, enough to supply anticipated new growth for the next twenty years. Ever more problematic is the concern that climate change induced drought might lead to drastic curtailment of all 'Post-Compact' water rights. Such curtailment could include shutting off half of the water which is now used by the major municipalities of the Front Range of Colorado where 75% of the state lives.

There is at least one bright spot on the river. For the last two years Reclamation has been working on an Environmental Impact Statement on how to share shortages and operate Powell and Mead during drought. This effort has lead to a noteworthy and imaginative agreement among the seven Colorado River states and Reclamation should issue a Record of Decision later this year. However, given climate change projections, I fear that this agreement will not be enough and the states will soon have to deal again with the delicate issue of not enough water for too many people.

Better Federal Management of Climate Change Science

We need a better way to manage the nation's overall climate change science enterprise. This is a critically important national problem yet the existing management structure seems ill-suited to

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[4] For an overview, see http://wwa.colorado.edu/products/forecasts_and_outlooks/intermountain_west_climate_summary/wwa_may_2007.pdf

[5] See for example: N. Christensen, D. P. Lettenmaier. 2006. A multimodel ensemble approach to assessment of climate change impacts on the hydrology and water resources of the Colorado River basin. Hydrology and Earth System Sciences Discussions, 3, 3727-3770. Hoerling, M. and J. Eischeid. 2006. Past Peak Water in the Southwest. Southwest Hydrology, 6(1). Milly, P. C. D., K. A. Dunne, et al. (2005). "Global pattern of trends in streamflow and water availability in a changing climate." Nature 438(7066): 347-350. Seager, R., M. Ting, et al. (2007). "Model Projections of an Imminent Transition to a More Arid Climate in Southwestern North America." Science: 1139601.

[6] Colorado's Grand and Summit counties now have over 1000 square miles of diseased and dying trees.

[7] Westerling, A. L., H. G. Hidalgo, et al. (2006). "Warming and earlier spring increase western US forest wildfire activity." Science 313(5789): 940-943.

the task. Does anyone really think an effective way to manage $2b of climate change science occurring in thirteen different federal agencies is by a small office overseen by a national interagency committee without budgetary authority? Despite good intentions, the Climate Change Science Program (CCSP) is a feel-good veneer on a problem that requires a far bigger response with an effective management structure. In addition, it is now time to include resource managers and decision makers along with scientists in the management of this very important program.

One sign of the current management problems is that despite being eager for climate change information, almost no water manager in the country is aware of the Climate Change Science Program. And they are certainly not aware of the twenty one Synthesis and Assessment Products being rolled out over the next two years, several designed specifically for decision makers[8]. Another example is the lack of resources for "decision support", the term used to describe information readily usable by policymakers. This is clear from both the small budget devoted to these activities and from actions of the program. I attended a CCSP workshop in 2005 on Decision Support attended by several hundred scientists yet there were just a handful of resource managers and decision makers in the audience. Please note that none of my comments are meant to malign the hardworking staff or management of the CCSP; they simply do not have the resources to pursue their mission effectively.

A National Climate Service, an idea under discussion by some in NOAA and in the academic community, might provide an umbrella to solve some of the climate variability and change needs of decision makers if it were crafted with care. This enterprise would "connect climate science to decision-relevant questions and support building capacity to anticipate, plan for, and adapt to climate fluctuations."[9] NOAA's new National Integrated Drought Information System (NIDIS) is one contribution to climate services. A national service would need to work closely with the many federal agencies that already deal in climate. Done effectively, this service would allow research scientists and resource managers to overcome the differences between the academic and management worlds. This concept already passed Congress in 1978 as Public Law 95-367 but has languished for lack of funding.

National scientific leadership should also entail a coherent policy for dealing with data. Simply put, no data means no science, and bad data leads to bad science. Good management also requires good data. In my experience with scientists, the first thing they love to argue about is data, the best example being the current dispute over hurricane trends. We will never end these arguments, but we should do our best to minimize these problems when possible. All data – National Weather Service data, USGS streamflow data, and National Resource Conservation Service snow and soil moisture data among many others -- should be covered by a consistent national plan and be provided adequate funding. Data collection is unfortunately the first thing that gets cut in time of shortfall. Meta-data, that is data about data, is especially critical ancillary data because it lets scientists cull bad data from good.

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[8] Namely 3.1: Climate Models: An Assessment of Strengths and Limitations for User Applications; 4.3: The effects of climate change on agriculture, land resources, water resources, and biodiversity; and 5.1: Uses and limitations of observations, data, forecasts, and other projections in decision support for selected sectors and regions.

[9] Miles, E. L., A. K. Snover, et al. (2006). "An approach to designing a national climate service." PNAS 103(52): 19616-19623.

Devote More Scientific Resources to Regional Problems

In the last two years, the confluence of the severe on-going drought, eye-opening information on far more serious droughts in past centuries supplied by tree-rings, and the growing scientific certainty over the causes of climate change, have provided a focus such that water utilities and managers are now ready to be full participants in the scientific enterprise on climate. This means, however, that we need to be able to provide regionally specific information on risks, such as changes in snowpack, timing of spring runoff, increases in water demand from temperature increases, amount of sea level rise, and changes in the length of the growing season. Unfortunately, to date, scientific assessments like the IPCC have focused on the global and continental scale effects of climate change and hence are of limited use to regionally focused decision-making.

One example of the burgeoning demand for climate change information came out of a water utility climate change summit early this year hosted by the San Francisco Public Utilities Commission (SFPUC) which I attended. This watershed event brought together some 250 water and wastewater utility leaders from around the nation, agency officials, top climate researchers, representatives from NGO's and the business community. Organized by and for water utility leaders, the Summit focused primarily on adaptation responses utilities are - and should be - thinking about in light of climate change. As a result of that Summit, a steering committee chaired by SFPUC General Manager Susan Leal and made up of managers of some of the largest utilities in the nation -- Metropolitan in Southern California, New York, Seattle, Las Vegas, Denver, Portland and San Diego-- has begun meeting to learn from one another and speak with a collective voice about what they need from federal, state, and regional agencies.

Much of the regional response needs to revolve around regionally specific climate modeling; this is an explicit concern of the utility group. Regional modeling is urgently needed to inform water supply and capital improvement planning in the water and wastewater utility community. We know the climate models have problems dealing with precipitation in mountains, and they do not represent important aspects of climate variability like decadal fluctuations. They most certainly are not a substitute for judgment. But they are the only tool we have for investigating likely future conditions and as such are critical. Used with care these models can provide an estimate of the range of possible future conditions. Despite their limitations, we must move forward with all forms of regional modeling as quickly as possible and this includes educating decision makers on their strengths and limitations.

Regional water management organizations need to work with regionally-based entities to solve their climate needs. During their 10-year existence, the existing RISA programs have provided valuable climate-related services and information for portions of the country. Seattle Mayor Nickels' leadership on climate change with the US Conference of Mayors is in part due to his connection to the Climate Impacts Group at the University of Washington. The California Applications Project at the Scripps Institution of Oceanography has been heavily involved with Governor Schwarzenegger's climate change initiative. My program has recently convened a panel of experts to draft a road map to help the Lower Colorado office of Reclamation prepare for climate change. Time over and again, RISAs have shown the capability of providing regionally relevant information on a whole host of issues ranging from information about past climates, to seasonal forecasts, and recently to climate change.

The RISAs provide one model of meeting regional climate needs that with additional resources could be scaled up to cover the nation. But this can not be done overnight. The effort takes time, dedication and commitment; overcoming the differences between the academic and professional management world can be challenging but innovative solutions come when academics, federal employees, and professionals share and combine their knowledge.

Conclusion

Drought and increased demand have combined to create a serious water supply problem on the Colorado River which climate change threatens to make far worse. To help the nation adapt to water supply problems caused by climate variability and change, we need more effective federal climate change science management and much more regionally-directed science. Both of these will require the involvement of resource managers and stakeholders in addition to scientists. Solutions will involve challenges to everyone. Scientists will need to understand needs and constraints of decision makers and adjust research to fit. Water Managers will need to understand the science better, and learn how to fit the uncertainty of climate change into their already significant capability to deal with variability. And even Congress will need to provide the necessary structure and oversight to allow the best climate change adaptation response possible.

Someone once said that the "proper response to uncertainty is insurance, not denial." It is time that we start acquiring 'insurance' against the effects of climate change by making sure that we have the necessary management, resources, tools and people to pursue critically needed water sector climate change adaptation measures. Thank you for the opportunity to address you today.

Bradley Udall Biographical Sketch

Brad Udall is on the research faculty at the University of Colorado where he serves as the Director of the CU-NOAA Western Water Assessment. The Assessment is an interdisciplinary NOAA-funded project designed to assist water managers and other users of climate data and information.

Brad was a contributor to the recent National Integrated Drought Information System plan and is a reviewer of the Intergovernmental Panel on Climate Change 4th Assessment Report. His research focuses on Colorado River hydrology, climate, law, and policy. As a frequently requested speaker, his recent engagements have included the U.S Conference of Mayors annual meeting, the University of Colorado Law School Conference on Climate Change, the ICLEI North American Congress, the Western Coalition of Arid States 2006 Winter Conference, the Western States Water Council, the National Association of Clean Water Agencies, and the San Francisco Public Utilities Commission Climate Change Summit.

Brad has an engineering degree from Stanford and an MBA from Colorado State University. He was formerly a consulting engineer and the managing partner at Hydrosphere Resource Consultants, where he worked on interstate litigation on the North Platte River, endangered species on the Columbia River, future Front Range supplies, and shortage issues on the Colorado River.

STATEMENT OF
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BEFORE THE
COMMITTEE ON ENERGY AND NATURAL RESOURCES,
SUBCOMMITTEE ON WATER AND POWER,
UNITED STATES SENATE,
HEARING ON
IMPACTS OF CLIMATE CHANGE ON
WATER SUPPLY AND AVAILABILITY IN THE UNITED STATES,
AND RELATED ISSUES FROM A WATER USE PERSPECTIVE

JUNE 6, 2007

Introduction

Mr. Chairman and Members of the Subcommittee, thank you for this opportunity to present testimony on the impacts of climate change on water supply and water availability in the United States.

Water is the life-blood of the Nation. Water keeps our bodies hydrated and clean and sanitizes our living spaces. Water in the soil grows the food we eat. We use water in the processing of food and fuel and the manufacture of products. Water flowing through our rivers produces electricity and transports cargo. Water is habitat and highway for fish and fowl. Water, liquid or frozen, is the Nation's playground in summer and winter.

The distribution of water across the Nation depends largely on climate. As discussed below, we believe the same factors causing global warming are changing the global water cycle.

Water availability can be measured in many ways: precipitation, streamflow, reservoir levels, snow pack, soil moisture, glaciers, and water tables. Precipitation is the gross income of our Nation's water budget; streamflow is the net income—what remains after the evapotranspiration tax has been extracted. Snow pack, reservoir levels, soil moisture and water tables represent the contents of our water bank accounts. The bank accounts are important for getting us through hot dry summers or the inevitable years of drought, but ultimately streamflow is the single best measure of disposable income in our national water budget.

How might water availability be expected to respond to a general climatic warming? The behavior of the water substance is very sensitive to temperature variations. Warm ice melts. Warm water expands. Warm air can hold more water vapor. Together with some more advanced atmospheric physics, which predicts subtle shifts in atmospheric circulation, these facts suggest the changes in water availability that can result from warming:

- Systematic regional increases and decreases of total annual streamflow.
- Rising sea level, resulting in increased risk of saltwater contamination of coastal freshwater supplies.
- Loss of snow pack, resulting in increased winter streamflow and winter flood risk and decreased summer streamflow.

Observed Streamflow Changes

During the last several decades, annual streamflow in the United States fluctuated widely over time. In 1988, the Ohio River gave 115 million acre feet of water to the Mississippi; the next year it gave 270 million acre feet. Such wide variation is a normal state of affairs.

The normal ups and downs of annual streamflow are superimposed upon more subtle, longer-term changes. In recent decades, the U.S. Midwest and Alaska became wetter, while the U.S. Southwest became drier. For example, the flow of the Ohio River at Metropolis, Ohio, during the last 30 years was 12 percent higher than during the preceding 48 years of observations. The flow of the Colorado River at Lees Ferry, Arizona, was 3 percent lower than during the preceding 71 years (after making adjustments for flow decreases associated with water withdrawals). The flow of the Yukon River at Eagle, Alaska, was 3 percent higher than during the preceding 26 years.

Long-term changes in seasonal timing of streamflow, possibly related to warming-induced changes in snowfall and snowmelt, have also been observed. As the western United States has warmed during recent decades, a tendency toward earlier timing of streamflow has been noted. Similar trends toward earlier streamflow have been seen in the northern tier of the eastern United States. In both regions, seasonal streamflows are typically rising and falling about a week earlier in the year during recent decades than in the prior period of record.

Causes of Observed Streamflow Changes: Normal Variability vs. Forced Climate Change

On the basis of statistical analyses of streamflow measurements, tree-ring records, and models, it appears that the recent long-term changes in annual streamflow observed over large areas of the United States were not unprecedented. Consequently, taken alone, these streamflow changes are not unequivocal evidence of forced climate change, but might be explained as mere manifestations of natural, internal variability in the climate system.

However, these data need not be taken alone. We have other sources of information, including streamflow measurements from around the world and computer simulations of changing climate in the United States and the rest of the world. The observed pattern of a wetter Midwest, a drier Southwest, and a wetter Alaska is also the pattern that emerges from climate models when they try to simulate streamflow during the 20th century. And, when we look at a global comparison of observed and climate-modeled changes in annual streamflow during the 20th century, this rough agreement for the United States is repeated over and over on the other continents. Analysis suggests that such a level of agreement across the globe would be very unlikely to arise simply by chance. On the basis of this global perspective, we conclude that the same factors causing global warming are changing the global water cycle. The change in the global water cycle, in turn, contributes to the observed changes in streamflow and water availability in the United States.

The earlier streamflow timing observed in the western and northeastern United States has been correlated with rising temperatures, but changes in precipitation amounts and timing have also played a role. Changes in streamflow timing have not been clearly attributed to forced climate change. However, we can say that the observed changes in streamflow timing are qualitatively consistent with expected impacts of forced climate change.

Predicting Future Water Availability

It is not valid simply to extrapolate the observed past changes in water availability forward into the future. However, the demonstrated skill of climate models in simulating the global pattern of 20th-century change in annual streamflow means that those models are credible, though far from perfect, tools for looking into the future. Given best assumptions about future atmospheric carbon dioxide concentrations and other drivers of climate change, these models project a long-term drying trend in the Southwest and moistening trends in the Midwest and Alaska. The drying trend in the Southwest can be expected to imply also an increasing probability of occurrence of Southwestern drought.

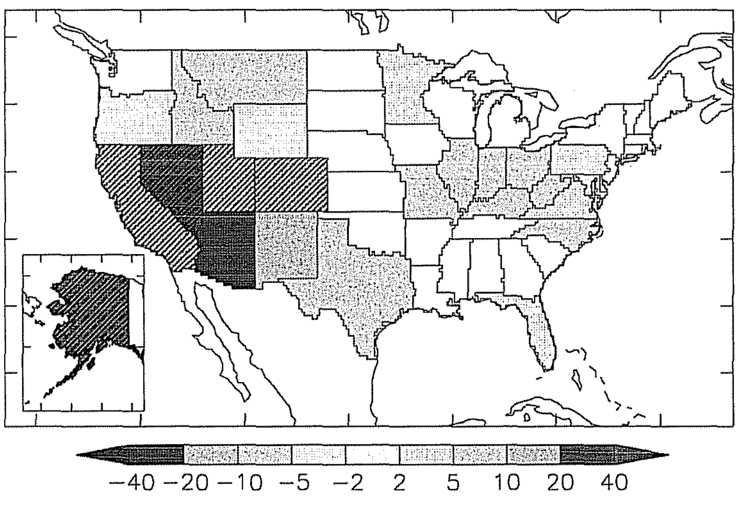


Figure. Model-projected percentage change in production of streamflow, by State, from 1900-1970 to 2041-2060. Colored States: more than 66 percent of 12 climate models agreed on the direction (increase vs. decrease) of change. Diagonal stippling: more than 90 percent of models agreed.

These projections, at best, are only crude caricatures of the real future. Are they the best that we can realistically hope for? Not at all. There is much room for improvement:

- Climate models typically represent conditions over areas larger than the State of Maryland by a single point. Such an approach has been adequate to assess global warming. However, climate varies geographically on a much finer scale, especially in mountainous regions. Therefore, to assess practical impacts on water and to design, plan, and implement needed adaptations, water managers need information on a much finer spatial scale, more like that of a county. To deliver this, much-higher-resolution climate models are needed.

- The Nation has no comprehensive network of streamflow measurement stations dedicated to monitoring long-term changes in streamflow in natural, developed, and developing environments across the national landscape. The available measurements, assembled from stations established for other purposes, have proven critical for the progress that has been made in detecting global changes in water availability. However, keeping higher-resolution models honest and tracking ongoing changes in water availability will require higher-resolution measurements.

- Climate models have only begun to include the effects of water-resource development, land use, and land-cover change on climate. This has not been identified as a crucial impediment for global analyses, but it probably matters at the finer spatial scale of water management.

- Water shortages come about when supply falls short of demand. Increased demand can create shortage, even when supply is stable. A change in climate causes a change in water demand, e.g., for irrigation and for natural ecosystems. Our understanding of this relation between climate and water demand needs improvement.

- Production of better climate information is necessary but not sufficient to assess future impacts. Climate information needs to come in a form that is relevant to water management. In order to ensure the relevance of climate-model information to water managers, accelerated and continuing dialogue will be needed between climate science and water managers.

- To make best use of available information in a changing climate, water management will need to adopt more flexible tools than those that have sufficed in the past. These new tools, unlike those that currently do the lion's share of water-system planning and design, must recognize that climate will change during the lifetime of a project and that estimates of the changing climate are uncertain. This will require a sea change in the field of water management. Such a change will not be accomplished without a concerted effort by government, academia, and professional societies.

Mr. Chairman, thank you for this opportunity to present testimony. I will do my best to answer any questions that you or other Members of the Subcommittee may have on this topic.

Statement of Terry Fulp, Area Manager
Boulder Canyon Operations Office
Bureau of Reclamation
Department of the Interior
Before the
Senate Energy and Natural Resources Committee
Subcommittee on Water and Power

June 6, 2007
Hearing on Climate Change and its Impact on Western Water

Madam Chairwoman and Members of the Subcommittee, my name is Terry Fulp, and I am the Area Manager at the Boulder Canyon Operations Office at the Bureau of Reclamation. It is a pleasure to be here today alongside the U.S. Geological Survey (USGS) to discuss the Bureau of Reclamation's operations, and the state of the science on global climate change.

There is extensive study, and discussion, within the scientific community about whether the West is experiencing warmer temperatures, longer growing seasons, earlier snowpack runoff, and more precipitation occurring as rain rather than snow. As the predictive capabilities of climate change models improve, western water resource management is looking to where and how to incorporate new climate change information.

A report released earlier this year from the National Academies of Science on Colorado River Basin Water Management concluded that "higher temperatures will result in less upper basin precipitation falling as snow, increased evaporative losses, and will shift the timing of peak spring snowmelt to earlier in the year." Reclamation is evaluating methodologies for incorporating climate change information into its west-wide operations.

Fortunately, Reclamation already possesses operational flexibility to respond to hydrologic change and fulfill its mission to deliver water and power in the West. Drought, flood, and wide climate variability are all common occurrences in the western United States. Given its mission, Reclamation must manage with this variability in mind. However, solutions and strategies for incorporating climate change science into water project operations is an emerging effort being undertaken by all western water management interests, not just Reclamation. Identifying the information needed will require coordinated participation from all the organizations that can provide expert climate and hydrologic sciences.

Reclamation works with its many partners to better understand and incorporate climate information into western water resource management. These partnerships include:

- Department of the Interior – United States Geological Survey (USGS) – The Reclamation Research and Development (R&D) Office is working with climate change experts in the USGS to help define the impact of changes in climate variability and climate change on western water resources. USGS and Reclamation management met in April 2006 to discuss collaboration and coordination efforts.

- Department of Energy (DOE) – Reclamation is working with DOE on evaluating general circulation climate models at the level of individual Reclamation drainage basins, and use of the resulting model information by Reclamation Regions.

- Department of Commerce – National Oceanic and Atmospheric Administration (NOAA) -- Reclamation is in the early stages of collaboration with NOAA Regional Integrated Science and Assessments Centers in the western U.S. to assist in data selection, interpretation, and understanding. These centers include the University of Washington Climate Impacts Group, the California Applications Group, the Western Water Assessment, and Climate Assessment for the Southwest. We are also collaborating with NOAA Earth System Research Laboratory to assist Reclamation to better understand the science surrounding climate variability and climate change.

- National Science Foundation (NSF) Funded Science Centers – These research centers include the National Center for Atmospheric Research and the National Center for Sustainability of Semi-Arid Hydrology and Riparian Areas. NSF also funds the Consortium of Universities for the Advancement of Hydrologic Science Inc., which has developed a Hydrologic Information System that may be of use to Reclamation as we seek to have better access to critical Hydrologic data. Reclamation plans to work with individuals in these centers and to utilize the available data to understand the impact of climate variability and climate change on western water resources.

- State of California – Department of Water Resources (DWR) – Reclamation is conducting joint research with DWR on assessing the risks of shifting climate on Reclamation's water and power operations This effort focuses on the Central Valley and State Water Projects. Additional partners include the U.S. Army Corps of Engineers, USGS, Scripps Institute, and Santa Clara University.

- U.S. Department of Agriculture's Natural Resources Conservation Service (NRCS) – NRCS's Snowpack Telemetry (SNOTEL) network provides an extensive, automated system designed to collect snowpack and related climate data in Alaska and the western United States which can be used to produce water supply forecasts. NRCS's Soil Climate Analysis Network (SCAN) is an information system designed to provide data on soil moisture and climate information from a number of different sources.

Secretary Kempthorne has convened a Climate Change Task Force chaired by Deputy Secretary Lynn Scarlett. In testimony delivered April 26, 2007, the Deputy Secretary spoke about the Task Force to the House Interior Appropriations Subcommittee. She explained that uncertainties persist on the timing, scale, and site-specific incidence of climate change impacts. Widely respected models differ in their projections about precipitation patterns, changes in vegetation, extent of sea level rises, and so on. Moreover, global climate modeling is just beginning to provide descriptions and projections at the regional and smaller scales that are needed to be useful for land managers on the ground.

To address this, the Task Force has designated three subcommittees. The first is currently reviewing the legal and policy issues associated with reviewing climate change effects in land-use planning. The second subcommittee focuses on land and water management, and cataloguing impacts relevant to Interior managed lands and waters. And the third subcommittee will focus on whether modeling might be developed at regional scales to better project more location-specific changes to the landscapes we manage. The three subcommittees will evaluate information needs and whether new types of monitoring might strengthen our understanding of on-the-ground trends in water availability and timing of flows, vegetative patterns, movement of species and so on.

Reclamation will continue to develop these partnerships to better understand and incorporate climate information into western water resource management. However, we do not believe that operational changes to release patterns or storage levels at major water facilities are warranted at this time. In order for new operational regimes to be warranted, Reclamation would look for much more specific, real-time hydrologic indicators at the basin level than currently exist, to show that runoff and inflows are occurring far outside the normal range. In some locations, methods may be available for linking climate change information to actual runoff. But more specific data to inform those methods is needed, and Reclamation would look for a dramatic change in the timing and volume of inflows beyond the capability of current operations and flood plans before implementing substantial changes in operations.

We also continue to work with our water users to institute improved water management and conservation in order to be better prepared for any possible future impacts associated with climate change. Our Water 2025 and Water Conservation Field Services Program, as well as current processes to analyze shortage sharing and coordinated water operations in the Colorado River Basin, all are important in this effort.

Together, and with the support of Congress and our customers, we believe that these activities will make Reclamation well-equipped to adapt to climate change impacts if and when they bring about new hydrologic regimes within the river basins of the West.

This concludes my written statement. I am pleased to answer any questions the subcommittee may have.

Rose, Laura

From: Rose, Laura
Sent: Friday, June 15, 2007 12:59 PM
To: Childs, David; Menard, Rosemary; Behmaram, Vahid
Subject: BCC 6-26-07, Continued - TEC 1 Staff report for review and approval

Attached for your review and approval is the revised staff report, revised Amendment No. 1, and new attachment C.

06-26-07 Staff Report TEC1.doc... Amendment No. 1 packet.pdf Attachment C TROA Briefing Doc...

Laura Rose
Administrative Secretary
Water Resources (775)954-4661

U.S. Senate

Energy and Natural Resources

Subcommittee on Water and Power

Honorable Jeff Bingaman, Chairman

Testimony provided on

The impacts of climate change on water supply and availability in the U.S.

Wednesday, June 6, 2007

By

Timothy F. Brick

Chairman, Metropolitan Water District of Southern California

700 N. Alameda Avenue

Los Angeles, CA 90012

Chairman Bingaman and Members of the Subcommittee, thank you for this opportunity to testify regarding the impacts of climate change on water supply and availability in the U.S. My name is Timothy Brick, and I am the Chairman of the Board of the Metropolitan Water District of Southern California.

For more than 75 years Metropolitan Water District has provided imported water to the Southern California region from the Colorado River and the State Water Project originating in Northern California. Our mission has been to be the wholesale provider of high quality, reliable drinking water supplies primarily for municipal and industrial use. In recent decades, we have begun to diversify our resources and commit to contingency planning in order to live up to our mission.

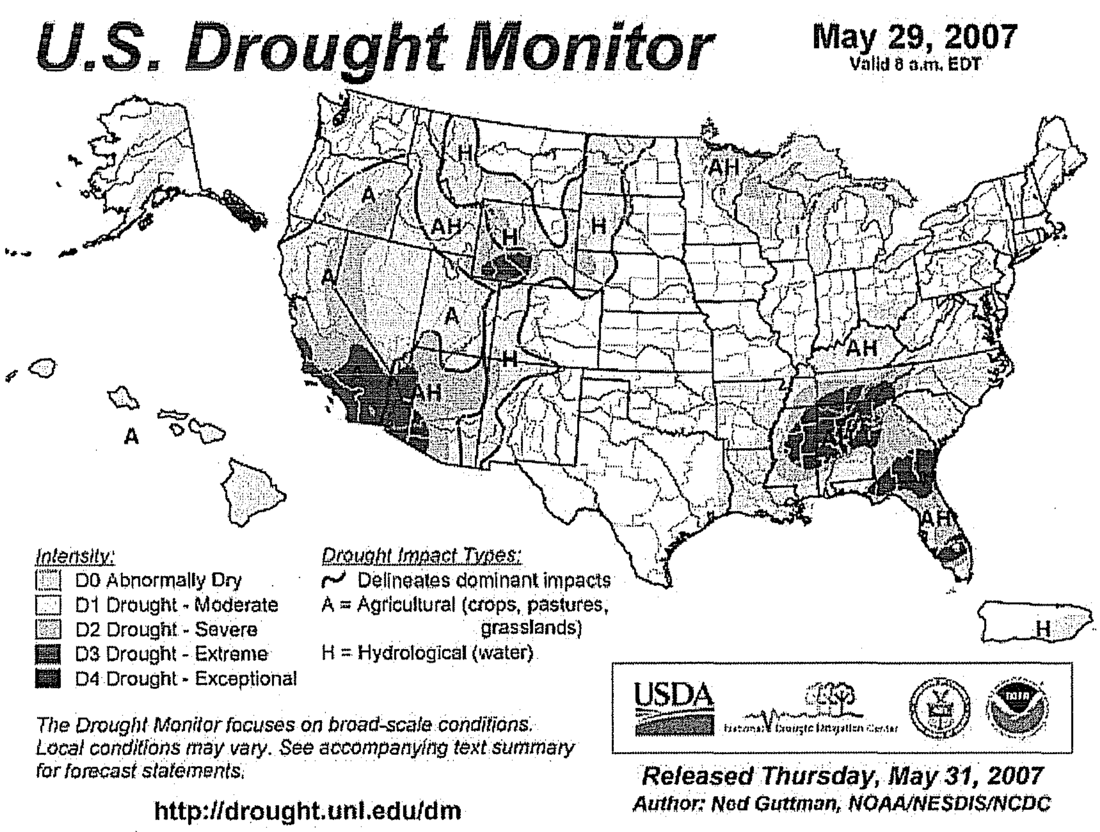
Metropolitan Water District is the nation's largest provider of imported water to an urban area. The population today in our service area is more than 18 million, and it is projected to rise to 22 million by 2030. Metropolitan is comprised of 26 member public agencies that service an area spanning 5,200 square miles and six southern California counties.

Climate Change

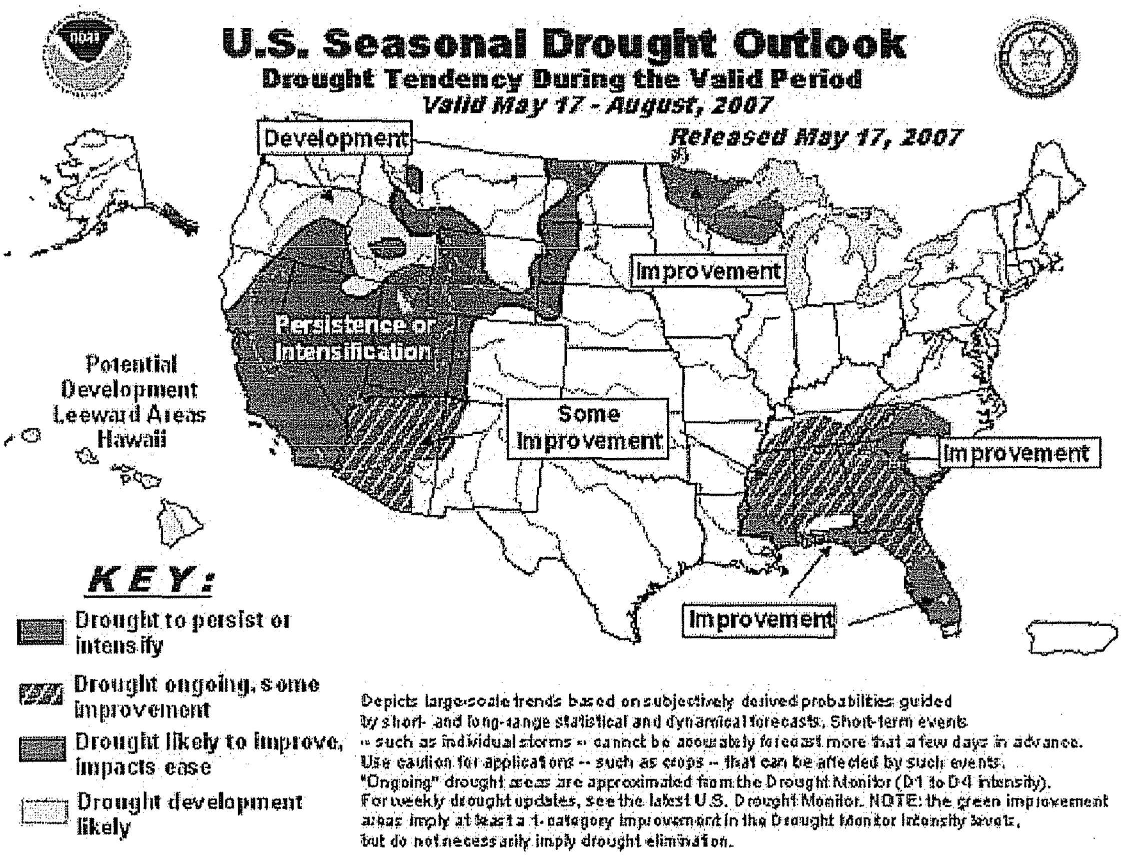
Metropolitan's latest challenge is one shared by not only the water community, but also the global community as a whole. California's history shows us that change in climate and weather, both natural and human-induced, are inevitable.

This climate change will have a dramatic impact on water supplies and demands and will necessitate a strong ethic of water use efficiency in our communities as well as the aggressive development of innovative, alternative water supplies to meet growing water needs.

Southern California is currently experiencing its driest year on record. Since July 1st 2006, Los Angeles has received only 3.21 inches of rainfall as compared to the normal of 15 inches per year. This year seems to be a continuation of a critically dry weather trend. In the most recent nine years, Los Angeles has averaged only eleven inches per year, 27% below normal.



On a larger scale, most of the western United States is experiencing record low precipitation and runoff. For the first time in Metropolitan's history, there are critical dry weather conditions occurring concurrently in our service area of Southern California as well as in the watersheds for our Colorado River and State Water Project water supplies. These regional climate trends are shown in the recent drought outlooks provided by the National Oceanic and Atmospheric Administration.



Colorado River Water Supplies

A report released by the National Research Council in February 2007 looked at past climate and streamflow conditions in the Colorado River and raised concerns regarding the long-term adequacy of Colorado River water supplies.

The western United States, particularly the region that depends on Colorado River supplies, has been experiencing drought conditions since the late 1990s. Years 2002 and 2004 are among the 10 driest years on record in the upper basin states of Colorado, New Mexico, Utah and Wyoming. Correspondingly, water storage in the basin's reservoirs has dropped sharply and now is at the lowest level since their initial fillings many decades ago.

It is now known that water allocations between the upper and lower Colorado River basin, as governed by the Colorado River Compact of 1922, were based on a short record of relatively high annual flows of 15 million acre-feet annually on the Colorado River. Recent patterns as well as reconstructed river flows based on tree-ring data dating back several centuries indicate that the past water management decisions on river water allocations and use may be overly optimistic of future water availability as annual flow could be 10 to 15 percent less than the 1922 estimate. Some experts would say even more.

Temperature records across the Colorado River basin and the western United States document a warming trend over the past century. Most recent climate model projections suggest that temperature across the region will continue to rise in the foreseeable future. Higher temperatures will result in less snowfall, increased evaporation losses, and shifting of snowmelt to earlier in any given year. The preponderance of scientific evidence suggests reduced Colorado River streamflow and water supplies, as well as increasing severity, frequency, and duration of future droughts.

In addition, the western United States is experiencing rapid population growth, further increasing the pressure for Colorado River water supplies. For example, population grew 66% in Nevada, 40% in Arizona, and 30% in Colorado from 1990 to 2000; these three states ranked number 1,2, and 3 in terms of highest percentage population growth during the last Census.

Better understanding of past climate and streamflow conditions of the Colorado River, rapid population growth and increasing water demands in the region, an apparent climate warming, and warnings from many climate model simulations have cast great uncertainty in the reliability of future Colorado River supplies to southern California and the Southwest.

California State Water Project

Last year the California State Department of Water Resources released a report titled "Progress on Incorporating Climate Change into Management of California's Water Resources." The report was prepared in response to Governor Schwarzenegger's Executive Order S-3-05 establishing California greenhouse gas emissions targets.

This report utilized four climate scenarios from two global climate models and downscaled potential ranges of change to the State Water Project watershed to analyze potential impacts. While the report does not represent a comprehensive assessment of the climate change impact, it does reveal at least three major potential impacts that constitute growing concerns for water managers.

<u>Runoff</u>

The first concern is related to the timing of snowmelt runoff. Studies suggest that warmer temperatures during the past half-century have brought significant changes in the seasonal timing of runoff. Smaller spring snow packs are a very real possibility and earlier melting of these natural reservoirs. When warmer temperatures in the winter translates into more rain and/or less snow in our Sierra Nevada mountains, it will severely lessen the ability to store water for peak summer water needs, avoid costly flooding, and otherwise manage fresh water - an increasingly scarce resource.

Water Quality

Water quality is also a concern linked to climate change. A higher sea level would likely bring increased salinity levels intruding on the freshwater system that is already vulnerable to salt water intrusion, and could further jeopardize levee stability, possibly leading to larger and more frequent failures like one that happened last year. Long periods of dry weather can also bring water quality challenges as contaminants typically accumulate on land surfaces. When the rain returns, it carries these contaminants in the runoff, making water treatment more difficult.

Extreme Weather Conditions

The third concern is linked to the possibility of extreme weather events that change the frequency of storm and drought conditions. Extreme weather conditions bring about many challenges, water quality being only one. Storage becomes another challenge as managers are caught in a tradeoff between storing water for future dry periods and lowering reservoirs before the onset of a flood season to protect downstream communities.

Climate change impacts further accentuate the variability and uncertainties surrounding water supplies from the State Water Project system.

Metropolitan's Policy on Climate Change

In March 2002, our board adopted policy principles on global climate change as related to water resource planning. The principles stated in part that "Metropolitan supports further research into the potential water resource and quality effects of global climate change, and supports flexible "no regret" solutions that provide water supply and quality benefits while increasing the ability to manage future climate change impacts."

Metropolitan's Response

The policy principles are reflected in Metropolitan's Integrated Resource Plan (IRP). Metropolitan and its member agencies have developed an IRP water resource portfolio that emphasizes diversification and adaptability of supply sources to manage current and future uncertainty. The IRP has also placed an increasing emphasis on local supplies such as conservation, water recycling and groundwater recharge.

Metropolitan built a new storage reservoir in the late 1990's in order to store water when it is plentiful during wet years for use in dry periods. In addition, Metropolitan is completing a large project called the Inland Feeder that will also expand our ability to obtain water from the Colorado River and State Water Project when it is available and to provide greater system reliability and flexibility.

Metropolitan has also forged many agreements in the past few years to store water in groundwater basins within and outside of southern California. Our cumulative investment in groundwater storage through 2006 was more than $400 million for groundwater storage augmented by $45 million of state grants.

Metropolitan also recognizes that importing water requires a large amount of energy. For example, importing an acre-foot of water via the State Water Project requires 3,200 kwh, and an acre-foot of Colorado River supplies requires 2,000 kwh. The IRP places increased emphasis on less energy consuming local water resources.

The greatest concentration of effort and resources in recent years has been in the area of conservation. Metropolitan has made a cumulative investment of $251 million in conservation. Metropolitan has long been an advocate and supporter of water conservation providing financial incentives to member agencies to grow conservation programs in their service areas through a variety of programs and rebates. Conservation has occurred in both residential and business sectors with Metropolitan offering guidance and financial incentives to use more water-efficient technologies. The most recent push has been in the area of outdoor conservation. Our California Friendly® program is an umbrella for many different programs that promote waterwise lifestyle choices.

Today, the California Friendly umbrella extends over a wide area of Metropolitan-sponsored programs that include retail partnerships to encourage of native and California Friendly plants in the product mix of large home improvement stores; a bewaterwise.com Web site that hosts as many as 3,000 visitors a day; and a landscape rebate program for new homes and a model home program with incentives for new home builders to install more efficient water saving devices in their model homes.

In recent years, Metropolitan has helped to bring about more than 85 water recycling and groundwater recovery programs by providing financial incentives to member agencies. Metropolitan has invested about $215 million through 2006 into these projects, which produce 128,000 acre-feet per year, equivalent to the water needs of over 600,000 people.

Metropolitan's diverse water resource portfolio continues to include imported supplies from the Colorado River and California State Water Project. To better manage the water systems for ecosystem health and competing needs, Metropolitan has shifted the timing of deliveries from these sources to wetter years or wetter periods when there is less impact on the fisheries and environment. To further efforts towards proper management of these supplies, Metropolitan has been participating with the other Colorado River basin states to provide recommendations to the U.S. Bureau of Reclamation on how the river system should be managed. Similarly, Metropolitan is a participant with other interests within the State of California on improvements to the Sacramento-San Joaquin River Delta system, which is the hub of water deliveries for the State Water Project. The goal is to more effectively manage water supply, water quality, and environmental needs. Both the efforts on the Colorado River system as well as the State Water Project Delta system will face critical decisions in the coming year.

Conclusion

The great challenges presented by the uncertain effects of climate change and increasing demands on the scarce freshwater supply mean we cannot afford to wait. Metropolitan, and the water community as a whole, needs to partner with the scientific community to conduct further research in assessing risks and integrating them into water management decisions. Metropolitan will continue to implement "no regrets" actions that incorporate climate change into our planning and investments in infrastructure, energy management and water supply development. Importantly, aggressive conservation and water use efficiencies must be practiced within California's communities and businesses to use our limited water supplies wisely and to protect the environment and ecosystems that will be stressed by climate change.

To support Metropolitan's continued supply diversity, and better adapt to climate change and other impacts, it is imperative that decisions regarding the Delta's ecosystem, levee and other infrastructure improvements. In addition, the Colorado River basin states initiatives and water management programs must be implemented to assure proper management of Colorado River resources during this extended drought.

Finally we need greater collaboration and partnerships with governmental agencies, non-governmental organizations, and other entities to implement solutions that provide benefits in multiple areas such as water quality and quantity, ecosystem health, and reduced energy usage. The federal government should play a key role in addressing uncertainty with regard to climate change by being a direct participant in the State of California's efforts on the Delta, Colorado River, and local water management. Metropolitan stands ready to work cooperatively and collaboratively with you and the federal agencies that you oversee.