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Good morning, Mr. Chairman and members of the Committee. Thank you for inviting me to speak with you today about the National Integrated Drought Information System (NIDIS); the information/data currently available to local, state and regional water decision-makers; and how we can improve the information available to these decision-makers for adapting to current and future drought conditions.

My name is Roger Pulwarty; I am a Physical Scientist in the National Oceanic and Atmospheric Administration's (NOAA's) Climate Program Office and the Director for the U.S. National Integrated Drought Information System (NIDIS). I had the honor of serving as a lead author on the Intergovernmental Panel on Climate Change (IPCC) Working Group II, in Chapter 17, Assessment of Adaptation Practices, Options, Constraints and Capacity, and on the IPCC Special Report on Climate Change and Water Resources released this past April. I am also a lead author of the U.S. Climate Change Science Program (CCSP), Synthesis and Assessment Report on Weather and Climate Extremes in a Changing Climate and the Unified Synthesis Report. My role in these reports focuses on impact assessment and adaptation responses.

In general, NOAA's climate programs provide the nation with services and information to improve management of climate sensitive sectors, such as energy, agriculture, water, and living marine resources, through observations, analyses and predictions, decision support tools, and sustained user interaction. Our services include assessments and predictions of climate change and variability on timescales ranging from weeks to decades for a variety of phenomena, including drought. In this testimony I will highlight: (1) present drought-related adaptation measures being undertaken in the water sector across the U.S., and (2) the role of the NIDIS in improving our capacity for responding to drought.

Drought is not a purely physical phenomenon, but is an interplay between water availability and the needs of humans and the environment. Drought is a normal, recurrent feature of climate and while its features vary from region to region, drought can occur almost anywhere. Because droughts can have profound societal and environmental impacts, there are several definitions of drought, each correct in its use. These definitions include meteorological drought, which is defined by the magnitude of precipitation departures below long-term average values for a season or longer; agricultural drought, which is defined as the soil moisture deficit that impacts crops, pastures, and rangelands; and hydrological drought, which is defined by significant impacts on water supplies. NOAA provides information on all three types of droughts in its U.S. drought information products.

Drought is a unique natural hazard. It is slow in onset, does not typically impact infrastructure directly, and its secondary effects, such as impacts on tourism, commodity markets, transportation, wildfires, insect epidemics, soil erosion, and hydropower, are frequently larger and longer lasting than the primary effects. Primary effects include water shortages and crop, livestock, and wildlife losses. Drought is estimated to result in average annual losses to all sectors of the economy of between $6 to 8 billion (in 2002 dollars; *Economic Statistics for NOAA*, April 2006, 5th edition). The costliest U.S. drought of the past forty years occurred in 1988 and caused more than $62 billion (in 2002 dollars) of economic losses (*Economic Statistics for NOAA*, April 2006, 5th edition). Although drought has not threatened the overall viability of U.S. agriculture, it does impose costs on regional and local agricultural economies. Severe wild fires and prolonged fire seasons are brought on by drought and strong winds. These fires, similar to the ones in California this past year, can cause billions of dollars in additional damages and fire suppression costs.

Recent IPCC reports, including the recent Technical Report on Climate Change and Water Resources, highlight emerging needs for the development and communication of climate and climate impacts information to inform adaptation and mitigation across sectors when changes are beyond average climate conditions and extremes. Drought risk management provides an important prototype for testing adaptation strategies across the full spectrum of climate timescales. Most communities (and countries) currently manage drought through reactive, crisis-driven approaches. Experience shows that effecting change in managing climate-related risk is most readily accomplished when: (1) a focusing event (climatic, legal, or social) occurs and creates widespread public awareness; (2) leadership and the public are engaged; and (3) a basis for integrating monitoring, research, and management is established. The NIDIS offers the nation a mechanism to achieve this latter service requirement. The IPCC 4th assessment (2007) and the CCSP reports offer impetus for integrating knowledge about the nature of societal and environmental vulnerability, attribution of the relative influences of climate variability and change, and for services to support federal, state and local adaptive responses to the full spectrum of climate. This impetus is further strengthened by the ongoing debates as seen occuring in connection with water scarcity in the West since 1999 and in the Southeast since 2007, along with declining Great Lake water levels since 1986.

Given that a drought occurs when water supply is insufficient to meet water demand, drought impacts are evaluated relative to the demand from environmental, economic, agricultural, and cultural uses. The impacts of past droughts have been difficult to estimate. This problem results from the nature of drought, which is a phenomenon with slow onset and demise that does not create readily-identified and discrete short-term structural impacts. Drought may be the only natural hazard in which the secondary impacts can be greater than the more identifiable primary impacts, such as crop damage. Impacts may continue to be felt long past the event itself as secondary effects cascade through economies, ecosystems, and livelihoods.

The *National Integrated Drought Information System Act of 2006* (*NIDIS Act*; 15 U.S.C. § 313d and § 313d note) prescribes an approach for drought monitoring, forecasting, and early warning at watershed, state and county levels across the United States. Led by NOAA, this approach is being developed through the consolidation of physical/hydrological and socio-economic impacts data, engaging those affected by drought, integration of observing networks, development of a suite of drought decision support and simulation tools, and the interactive delivery of standardized products through an internet portal (www.drought.gov). NIDIS is envisioned to be a dynamic and accessible drought risk information system that provides users with the capacity to determine the potential impacts of drought, and the decision support tools needed to better prepare for and mitigate the effects of drought.

As requested in the 2004 Western Governors' Association Report, *Creating a Drought Early Warning System for the 21st Century: The National Integrated Drought Information System*, NIDIS is being designed to serve as an early warning system for drought and drought-related risks in the 21st century. With these guidelines in mind, the explicit goal of NIDIS is to enable society to respond to periods of short-term and sustained drought through improved monitoring, prediction, risk assessment, and communication.

Over the next five years, NIDIS will build on the successes of the U.S. Drought Monitor, Seasonal Outlooks, and other tools and products provided by NOAA and other agencies to effect fuller coordination of relevant monitoring, forecasting, and impact assessment efforts at national, watershed (e.g. the Colorado Basin), states (e.g. GA, AL, FL), and local levels. NIDIS is beginning to provide a better understanding of how and why droughts affect society, the economy, and the environment, and is improving accessibility, dissemination, and use of early warning information for drought risk management. The goal is to close the gap between the information that is available and the information that is needed for proactive drought risk reduction. Federal monitoring and prediction programs that feed into NIDIS are also working with universities, private institutions, and other non-federal entities to provide information needed for effective drought preparedness and mitigation.

NIDIS will provide more comprehensive and timely drought information and forecasts for many users to help mitigate drought-related impacts. For example, hydropower authorities will benefit from enhanced water supply forecasts that aim to incorporate improvements in monitoring soil moisture, precipitation, and temperature for snowpack conditions into forecasting efforts and drought information for water management decisions. Municipalities and state agencies will have improved drought information, based on present conditions and past events, and forecasts when allocating both domestic and industrial water usage. Water resource managers will have access to more information when balancing irrigation water rights with the needs of wildlife. Purchasing decisions by ranchers for hay and other feed supplies will be enhanced through the use of drought information to identify areas of greatest demand and the potential for shortages. Changes in water quantity and quality due to climate change and other factors are expected to affect food production and prices.. Farmers will be better positioned to make decisions on which crops to plant and when to plant them. Since drought information is used in allocating federal emergency drought relief, improvements in monitoring networks will also lead to more accurate assessments of drought and, as a result, emergency declaration decisions that better reach out to those communities in need of assistance. An example of a specific improvement in monitoring networks is the addition of soil moisture sensors to the climate reference network by NOAA/NIDIS. The identification of gaps in monitoring needed for early warning system development, primarily within snow cover, soil moisture, stream gauge, and ground water networks (in partnership with the U.S. Geological Survey), will be identified in NIDIS early warning pilot programs in selected locations. Also, in partnership with Department of Agriculture (USDA), priorities for snow cover/snow telemetry sites will be updated as need arises. Cross-agency partnerships to fill monitoring gaps will be developed with the interagency NIDIS Executive Council.

Data alone is not sufficient to ensure effective adaptation. A hallmark of NIDIS is the provision of decision support tools coupled with the ability for users to report localized conditions. To this end, NIDIS will link multi-disciplinary observations from a number of sources to ‘on-the-ground’ conditions that will yield value-added information for agricultural, recreational, water management, commercial, and other sectors. Multi-disciplinary observations include land surface conditions (e.g., for fire/fuel risk and soil moisture), streamflow and precipitation observations, climate models, and sectoral and environmental impacts information (to identify potential high impact areas or sectors for different types of drought events). Also, impacts information (i.e., how drought is affecting a location, how similar/past droughts have affected the location) will be provided by NIDIS, as required in the *NIDIS Act*, and as recommended by the Western Governors Report, and decades of study on the types of information leads to effective early warning triggers for response.

The first step towards accomplishing these goals was to produce an implementation plan. With the results of deliberate and broad-based input from workshops held with federal, state, and local agencies, academic researchers, and other stakeholders, the NIDIS implementation plan was produced and published in June 2007. To provide guidance on system implementation, technical working groups were formed to focus on five key components of NIDIS. These components are public awareness and education, engaging preparedness communities, integrated monitoring and forecasting, interdisciplinary research and applications, and the development of a national drought information portal.

A great deal of progress has been made since the NIDIS program was established in December 2006. The U.S. Drought Portal, launched in November 2007 and hosted on the NIDIS website (www.drought.gov), is operational and providing comprehensive information on emerging and ongoing droughts, and enhancing the nation's drought preparedness. Other current NIDIS activities include conducting the first national workshop to assess the status of drought early warning systems across the United States, 17-19 June, Kansas City, MO. A NIDIS Southeast drought workshop was recently held in Peachtree City, Georgia, 29-30 April 2008 to begin coordinating drought early warning information systems for the Southeast region especially for the Appalachicola-Chattahoochee-Flint and the Alabama-Coosa-Tallapoosa basins encompassing the upper watersheds of Georgia to the coastal resources of Alabama and Florida.

While NOAA is the lead agency for NIDIS, NOAA works with numerous federal agencies, emergency managers and planners, state climatologists, and state and local governments, to obtain and use drought information. NOAA routinely disseminates drought forecast information via its National Weather Service (NWS) drought statements, and collaborates with state drought committees and the media to assure NOAA information is correctly understood and used. NOAA strives to provide an end-to-end seamless suite of drought forecasts, regional and local information, and interpretation via its Climate Prediction Center, six Regional Climate Centers, Regional Integrated Sciences and Assessments (RISA) including the Southeastern Climate Consortium, local NWS field offices and state climatologists. Efforts are underway to improve drought early warning systems including coordinating interagency drought monitoring, forecasting, and developing indicators and management triggers for societal benefit. The other major federal agencies involved in NIDIS are the Department of the Interior, USDA, the National Aeronautic and Space Administration, the Department of Energy, the Department of Homeland Security, the Department of Transportation, the Army Corps of Engineers, the Environmental Protection Agency, and the National Science Foundation. There is significant leveraging of existing observing system infrastructure, data, and products produced by operating agencies, for example, stations of the NOAA National Weather Service Cooperative Observer Program, USDA Natural Resources Conservation Service SNOTEL (SNOpack TELemetry) network, Soil Climate Analysis Network, National Climate Data Center Climate Reference Network, and the United States Geological Survey streamflow and ground-water networks, as well as the USDA-Joint Agricultural Weather Facility and the USDA-Natural Resources Conservation Service/Water and Climate Center Weekly Report - Snowpack/Drought Monitor Update. NIDIS also provides a framework for coordinating the research agenda among these agencies.

At present NOAA/NIDIS is supporting the development of new drought monitoring and prediction products and accelerating future improvements of NOAA’s operational climate forecast and application products through the use of competitive grants, and through the tailoring of the U.S. Drought Portal to add locally specific data and information at the level of watersheds and counties. Questions being addressed include early warnings of low flow conditions on the Colorado, on drought and fire risk, agriculture on the Southern Great Plains and the reliability of water supplies in the Southeast U.S.

Information services for adaptation on short-term (seasonal) or longer-term (multi-year) drought, will be important in coping with current climate vulnerabilities and early impacts in the nearterm, and will help build resilient economies as our climate changes, regardless of how that change is derived. It is important to note that unmitigated climate change could, in the long term, exceed the capacity of some natural, managed and human systems to adapt especially in drought prone –heavily developing regions such as the Southwest. If climate change results in increasing water scarcity relative to demands, future adaptations may include technical changes that improve water use efficiency, demand management (e.g. through metering and pricing), and institutional changes that improve the tradability of water rights. If climate change affects water quality, adaptive strategies will have to be developed to protect the ensuing human uses, ecosystems and aquatic life uses. It takes time to fully implement such changes, so they are likely to become more effective as time passes. The availability of water for each type of use may be affected or even limited by other competing uses of the resource.

Climate is one factor among many that produce changes in our environment. Demographic, socio-economic and technological changes may play a more important role in most time horizons and regions. As the number of people and attendant demands upon already stressed river basins and groundwater sources increase, even small changes in our climate, induced naturally or anthropogenically, can trigger large impacts on water resources. Present hydrological conditions are not anticipated to continue into the future (the traditional assumption). It will be difficult to detect a clear climate change effect within the next couple of decades, even if there is an underlying trend. Consequently, methods for adaptation in the face of these uncertainties are needed. Early warnings of changes in the physical system and of thresholds or critical points that affect management priorities become important. Water managers in some states are already considering explicitly how to incorporate the potential effects of climate change into specific designs and multi-stakeholder settings. Integrated water resources and coastal zone management are based around the concepts of flexibility and adaptability, using measures which can be easily altered or are robust to changing conditions. For example, in California and Nevada adaptive management measures (including water conservation, reclamation, conjunctive use of surface and groundwater, and desalination of brackish water) have been advocated as means of proactively responding to climate change threats on water supply. Consequently a complete analysis of the effects of climate change on human water uses should consider cross-sector interactions, including the impacts of and opportunities for changes in water use efficiency and intentional transfers of the use of water from one sector to another. For example, voluntary water transfers (including short-term water leasing and permanent sales of water rights) from agricultural to urban or environmental uses are becoming increasingly common in the Western United States. . An additional major challenge in the coming decades will be maintaining water supplies for environmental services, which support tourism, hunting, fishing and other recreational economies throughout the United States.

Adaptation is unavoidable because climate is always varying even if changes in variability are amplified or dampened by anthropogenic warming. Moreover, adaptation will be necessary to meet the challenge of demographic pressures and climate trends which we are already experiencing. There are significant barriers to implementing adaptation in complex settings. These barriers include both the inability of natural systems to adapt at the rate and magnitude of demographic, economic, climatic and other changes, as well as technological, financial, cognitive, behavioral, social and cultural constraints. There are also significant knowledge gaps for adaptation, as well as impediments to flows of knowledge and information relevant for decision makers. In addition, the scale at which reliable information is produced (i.e. global) does not always match with what is needed for adaptation decisions (i.e. watershed and local). New planning processes are attempting to overcome these barriers at local, regional and national levels in both developing and developed countries.

Adaptive capacity to manage climate changes can be increased by introducing adaptation measures into development planning and operations (sometimes termed 'mainstreaming'). This can be achieved by including adaptation measures in land-use planning and infrastructure design, or by including measures to reduce vulnerability in existing disaster preparedness programs (such as introducing drought warning systems based on actual management needs).

Major barriers to implementing adaptive management measures are adaptation itself is not yet a high priority, and that the validity of local manifestations of global climate change remains in question. Coping with the uncertainties associated with estimates of future climate change and the impacts on economic and environmental resources means we will have to adopt management measures that are robust enough to apply to a range of potential scenarios, some as yet undefined. Greenhouse gas mitigation is not enough to reduce climatic risks, nor does identifying the need for adaptations translate into actions that reduce vulnerability. By implementing mainstreaming initiatives, adaptation to demographic and climate change will become part of, or will be consistent with, other well-established programs to increase societal resilience, particularly environmental impacts assessments, adaptive management and sustainable development.

Climate variability and change affect the function and operation of existing water infrastructure — including hydropower, structural flood defenses, drainage, and irrigation systems — as well as water management practices. Observational records and climate projections provide abundant evidence that freshwater resources are vulnerable and have the potential to be strongly impacted by climate variability and change, with wide-ranging consequences on human societies and ecosystems. Observed warming over several decades has been linked to changes in the large-scale hydrological cycle. Several gaps in knowledge exist in terms of observations and research required to better understand the relationship between climate change and water issues. Observational data and data access are prerequisites for adaptive management, yet many gaps exist in observational networks. It is important to improve understanding and modeling of changes in climate related to the hydrological cycle at scales relevant to decision making. Information about the water-related impacts of climate change, including their socio-economic dimensions, is incomplete, especially with respect to water quality, aquatic ecosystems, and groundwater.

Early warning information and decision support tools that are currently being developed to better prepare our nation, locally and regionally, for drought include:

- Enhancing networks of systematic observations of key elements of physical, biological, managed and human systems affected by climate variability and change particularly in regions where such networks have been identified as insufficient;

- Strengthening and expanding water conservation and efficiency programs;
- Adopting integrated strategies at the federal level (including high level advisory councils) and support a framework for collaboration between research and management;
- Promoting local watershed efforts;
- Improving groundwater monitoring and management strategies;
- Developing usable drought management triggers for planning in agriculture, water, energy, health, environment, and coastal zones;
- Developing economic impacts assessment tools including the costs and benefits of various adaptations;
- Coordinating among drought monitoring and forecasting efforts at federal regional, state, and local levels; and
- Actively enagaging communities and states in monitoring, preparedeness, and planning.

The challenges of managing water supplies to meet social, economic, and environmental needs requires matching what we know with what we do. NOAA and NIDIS provide mechanisms for the federal government to help agencies, states and local communities meet their economic, cultural, and environmental water management challenges in a timely and efficient manner.

Thank you for inviting me to testify at this hearing today and I will be happy to answer any questions the members of the Committee may have.