SCIENCE AND TECHNOLOGY TO SUPPORT FRESH WATER AVAILABILITY IN THE UNITED STATES

November 2004

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SCIENCE AND TECHNOLOGY
TO SUPPORT
FRESH WATER AVAILABILITY
IN THE
UNITED STATES

Report of the

NATIONAL SCIENCE AND TECHNOLOGY COUNCIL
COMMITTEE ON ENVIRONMENT AND NATURAL RESOURCES

Subcommittee on Water Availability and Quality

November 2004

Photo courtesy of USDA Natural Resources Conservation Service

EXECUTIVE OFFICE OF THE PRESIDENT
OFFICE OF SCIENCE AND TECHNOLOGY POLICY
WASHINGTON, D.C. 20502

November 15, 2004

Dear Colleague:

The health of the American people and the economic growth of the Nation depend on continuing availability of clean fresh water. Water is fundamental to life and is a basic requirement for virtually all of our agricultural, industrial, and recreational activities, as well as for the sustained health of the natural environment. The recent drought in the western U.S. and the increasing number of conflicts over the allocation of limited water supplies amplify the need for a better understanding of water availability.

It is critical to continue and expand research and monitoring efforts to better understand the water cycle, its variability and relation to global climate change, and to provide basic information about quality and movement of water. The accompanying report provides a clear statement of need for coordinated science and technology efforts to understand the supply, human demand, and environmental requirements for fresh water in the United States. The report has been prepared by the Subcommittee on Water Availability and Quality, which is part of the National Science and Technology Council's Committee on the Environment and Natural Resources. This group advises and assists CENR and the NSTC on policies, procedures, plans, issues, scientific developments, and research needs related to the availability and quality of water resources of the United States.

The report provides the first step in the development of a coordinated plan to improve research to understand the processes that control water availability and quality, and to collect and make available the data needed to ensure an adequate water supply for the Nation's future.

Sincerely,

John H. Marburger, III
Director

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ABOUT THE SUBCOMMITTEE ON WATER AVAILABILITY AND QUALITY

The National Science and Technology Council (NSTC), a cabinet level council, is the principal means for the President to coordinate science and technology policies across the Federal Government. NSTC acts as a "virtual" agency for science and technology to coordinate the diverse parts of the Federal research and development enterprise.

An important objective of the NSTC is the establishment of clear national goals for Federal science and technology investments in areas ranging from information technologies and health research to improving transportation systems and strengthening fundamental research. This council prepares research and development strategies that are coordinated across Federal agencies to form an investment package that is aimed at accomplishing multiple national goals.

To obtain additional information regarding the NSTC, contact the NSTC Executive Secretariat at (202) 456-6101.

In 2002, the Office of Science and Technology Policy convened representatives of Federal agencies under the NSTC's Committee on the Environment and Natural Resources (CENR) to form the Subcommittee on Water Availability and Quality (Subcommittee). The purpose of the Subcommittee is to advise and assist the CENR and the NSTC on policies, procedures, plans, issues, scientific developments, and research needs related to the availability and quality of water resources of the United States. For the purpose of this Subcommittee, water resources are defined as fresh and brackish water in the atmosphere, streams, lakes, unsaturated zone, aquifers, and estuaries. The Subcommittee focuses on science issues and policy related to needed improvements in technology and research that will advance the goal of ensuring a safe and sustainable supply of water in the United States for human and ecological needs.

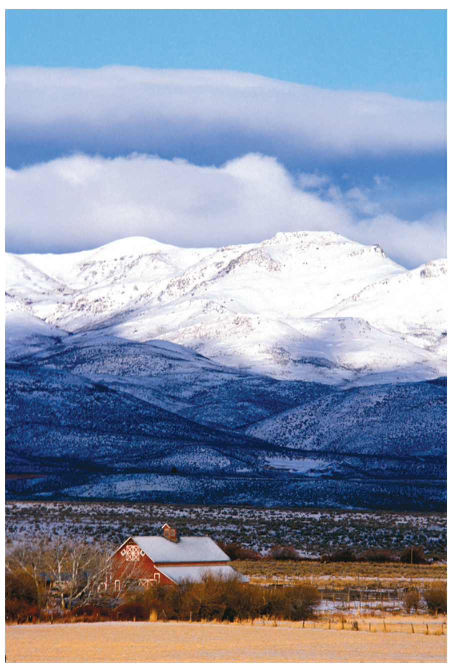


Photo courtesy of US Department of Agriculture

Does the United States have enough water?

We do not know.

We do not have an adequate picture of water availability at national, regional, and local levels. "National water availability and use has not been comprehensively assessed in 25 years" —U.S. General Accounting Office report, July 2003[1].

Why should we care?

"Water, which used to be considered a ubiquitous resource, is now scarce in some parts of the country, and not just in the West as one might assume. The water wars have spread to the Midwest, East and South as well. " Water "...conflicts are occurring within states, among states, between states and the federal government and among environmentalists and state and federal agencies." Tribal governments "... are pursuing several legal battles to reclaim their water rights." —Council of State Governments report "Water Wars", 2003[2].

How much water do we need?

We have a general idea of how much water is used for public water supply, industry, commerce, irrigated agriculture, livestock, and domestic purposes. Yet, "The accuracy and confidence limits of these water use estimates are not quantified." —National Research Council report, 2002[3]. In addition, the amounts also needed to maintain our natural environmental resources are not well known.

Does it matter if we don't know?

Decisions about use of our water resources can result in severe economic or environmental consequences when the decisions are based on poor information about water availability and use[4], or on badly flawed forecasts of future availability[5]. Water is essential to the success of agriculture and industry that are important for national, regional, or local economic well being. The words of President Dwight D. Eisenhower "The policies we adopt for the development of our water resources will have a profound effect in the years to come upon our domestic, agricultural, and industrial economy[6]" are just as relevant today as in Eisenhower's time.

What should we do?

- Improve coordination of existing federal, state, academic and private sector water resources research activities using a watershed-based approach.
- Make a direct connection between information needs of water managers and identification of water science and technology priorities.
- Use modern science and technology to determine how much water is currently available in our rivers, lakes, reservoirs, and aquifers, how much water is likely to be available in future decades at current or projected rates of use[1,7,8], and improve our understanding of the nation's water resources and their natural variability.
- Determine more precisely how much water is used for human needs, agriculture, industry, energy, and develop scientifically reliable methods to determine the amount of water needed for the environment[3,7,8].
- Evaluate alternatives in order to use water more efficiently, including technologies for conservation and supply enhancement, such as water reuse and recycling, as a way to make more water available and determine the factors that influence their adoption[2].
- Examine the factors that encourage the economical use, production, supply, and exchange of water.
- Improve tools needed for predictions (at time scales of days to decades) about the future of our water resources[2] to facilitate improved planning and more efficient operation of the water infrastructure.

PREFACE

Millions of Americans whose water is supplied by a public utility turn on their water faucets each day without a thought about where their water comes from. Those who are served by individual domestic wells may be more conscious of where their water comes from. However, most people rarely think about not having enough water for daily activities, unless power is interrupted, or a prolonged drought results in restrictions on water use, or a well becomes dry. Those same citizens may be aware that agricultural use of water is important for maintenance of food supply, but less aware that an even larger amount of water is involved in power generation, or that water is a key ingredient for the success of industry that is important for national, regional, or local economic well being. In recent years, the general population may have noticed news items in print or elsewhere concerning the water needs of the natural environment. Yet, the same general population may give little thought to the fact that competing demands for available water may give rise to decisions about water resources that could adversely affect agriculture, energy, industry, and the environment, not just whether or not they can use water for domestic needs without restrictions.

The purpose of this report is to state the need for coordinated science and technology efforts to address the growing requirement to understand the supply and demand for fresh water in the United States. In addition, the report attempts to address decision makers' need to assess current water resources and balance competing demands for water for human and environmental uses in order to ensure that adequate supplies are available for both for present and future generations. It describes high-priority new science and technology that is needed to improve the factual basis for decision making on these issues. The report builds on recent reports of the National Research Council[7,8] "Envisioning the Agenda for Water Resources Research in the Twenty-First Century" and "Confronting the Nation's Water Problems: The Role of Research". "Confronting the Nation's Water Problems: The Role of Research" provides an overview of water resources research funded by federal agencies and significant non-federal organizations. The National Research Council reports, combined with this report of the National Science and Technology Council, provide the basis for subsequent development of a strategy to address Federal research and development for U.S. water resources.

Photo courtesy of USDA Natural Resources Conservation Service

US Geological Survey

Introduction

We do not have an adequate picture of water availability at national, regional, and local levels.

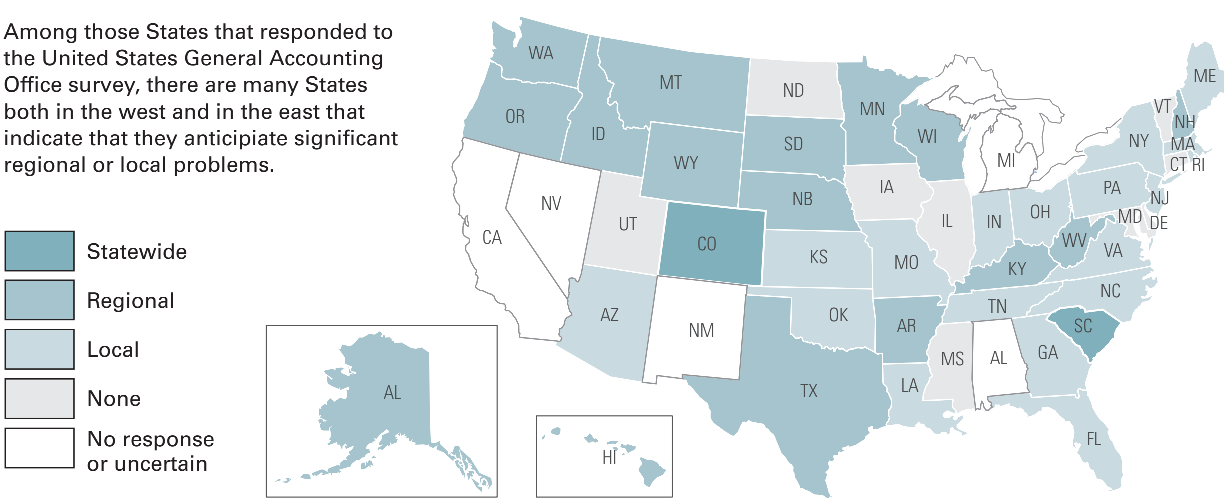
The last time National water availability and use was comprehensively assessed was 25 years ago[1]. Previous studies were undertaken in response to a Presidential Water Resources Policy Commission[9,10] and requests from Congress[11,12,13]. At the time, water availability and use evaluations focused on how much water was available for human activity and estimation of how much water was used by various human activities (urban, industrial, and agricultural).

Today, the water requirements of the natural environment, as well as for future economic development of tribes and the general public, are factors that also need to be considered. Further we recognize that climate variability is an important consideration in determining water availability now and in the future. Water managers need answers to questions such as:

- Will there be enough water available for their communities, farms and factories, over the coming months and over coming generations?
- Will there be enough water to satisfy the needs of the aquatic and riparian species and communities that the public values?
- How much water is there in their aquifer, watershed, reservoir, lake or wetland and how does that compare to various times in the past? Just as with their own finances, they want to know if the "account" is growing, shrinking, or staying about the same.
- Will the quantity of high-quality water decline given our current agricultural, mining, waterborne transportation, and industrial practices?
- Will application of current and future water conservation and technologies make more water available? What are the societal incentives necessary to promote the application of water conservation technologies, practices, and technologies?

Extent of state shortages likely over the next decade under average water conditions[1]

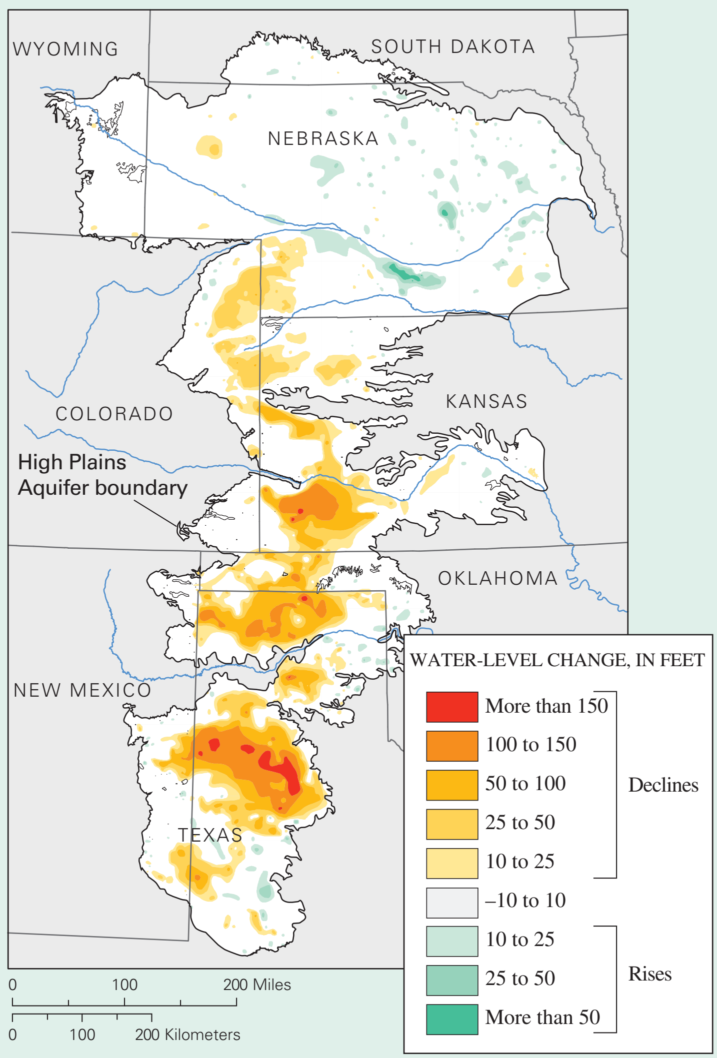
Among those States that responded to the United States General Accounting Office survey, there are many States both in the west and in the east that indicate that they anticipate significant regional or local problems.



Making decisions about water availability also requires an improved knowledge of the social and economic institutions which make decisions about water availability and use every day. Social and economic factors drive the demand for water (population growth, economic development, shifting social values) and supply of water (technological change and adoption). Further, the price incentives created by the institutions that allocate water serve a critical role for conditioning demand and stimulating supply. Social science can analyze how effectively the current policy and institutional structure achieves an efficient and equitable allocation of scarce water supplies across diverse needs, and evaluate alternative structures. Social science also can help to determine what is required to get different technologies adopted to make more water available. One example of this is low-flow bathroom fixtures and water-saving appliances have resulted in conservation of water at home by Americans over the last decade[11]. Crop irrigation and industrial use of water also have recognized

Defining the available resource — the High Plains Aquifer

One of the few syntheses of existing water resources information for a river basin or aquifer has been done recently for the High Plains aquifer[16]. This effort combined information from water-level measurements in over 8,000 wells, historical water-level measurements from 20,000 wells, previous studies that characterized the geologic framework and hydraulic properties of the aquifer, irrigated acreage estimated from satellite imagery in previous studies, U.S. Department of Agriculture census data, existing water use information, and a previous study of social and economic impacts of changes in water availability. In some parts of the aquifer declines have been more than 100 feet, which locally represents half of the saturated thickness of the aquifer. The average area-weighted water-level decline in the aquifer has been nearly 12 feet since 1920. The volume of water remaining in the aquifer as of 2000 is approximately equal to the volume of Lake Huron[16] or nearly 7 years of annual average flow of the Mississippi River at Vicksburg. Declining water levels have resulted in increased energy costs to pump ground water to use for irrigation. The High Plains Aquifer study is an example of what could be done in other basins or aquifers that could serve as a guide to decision makers about the status of the resource.



Water-level changes in the High Plains aquifer, predevelopment to 2000[16]

Urban sprawl, Las Vegas, Nevada

water savings in the past 10 years through water-saving technological advances and implementation of water conservation in response to market forces or legislation[11].

The nation will not have a comprehensive view of water availability without assessing the needs of human and natural system uses, accounting for the effect of variability in the natural system on water supply, and recognizing how social and economic institutions affect water availability.

"State Water managers expect freshwater shortages in the near future, and the consequences may be severe. Even under normal conditions, water managers in 36 states anticipate shortages in localities, regions, or statewide in the next 10 years[1]" (figure, page 1). In future years "…changes in the amount, timing, and distribution of rain, snowfall and runoff are probable, leading to changes in water availability as well as in competition for water resources[1]." Also, according to the National Research Council report of 2001[7], "In this new century, the United States will be challenged to provide sufficient quantities of high-quality water to its growing population." Thus, water resource decision-makers would benefit not only from an improved understanding of water availability in the future, but also from science and technology that address current water crises through reductions in water consumption. We need to focus available and emerging research and technologies on the question of how much water is available, particularly high-quality water, and how much water will be available months, years, or decades into the future.

Understanding the natural variability of our water resources, which are affected by both precipitation and temperature, is critical to hydrologic forecasting. Timing and type of precipitation are as important as the amount. Recent observations show that diminished snow accumulation and earlier snowmelt[14] can have profound implications for the amount of water that can be delivered to users or to aquatic ecosystems. Further, the primary challenge related to hydrologic forecasting is in forecasting coming variations in water availability (and water quality) not just amounts of water expected based on "average conditions." To make advances in forecasting, more comprehensive assessments of the amounts of water stored in the atmosphere, surface, and subsurface, as well as the exchange between these are needed[15] (sidebar opposite).

Why should we care if the United States has enough water?

Variability in our water resources and changing demands are resulting in increasing water scarcity across the United States. Water scarcity concerns are most notable in areas of the arid West, where surface-water withdrawals have been maximized and ground-water pumping has exceeded natural rates of aquifer recharge. Water scarcity is increasingly an issue in the more humid Eastern States as well. Limited storage, ground water level declines, salt water intrusion and depletion of streamflow needed for aquatic species are common problems in the East.

Lower Klamath River, California

Jodi Frediani

Salmon

Jack Ellwanger

Defining Ecosystem Water needs

Knowledge of the relation between organisms that either live in surface water, subsurface water, or on flood plains and the amount and timing of water needed to sustain their habitat has been of interest for some time, but particularly in the last decade. The field of Ecohydrology, for example, has only been in existence for a few years. This field of science "is concerned with the effects of hydrological processes on the distribution, structure, and function of ecosystems, and on the effects of biotic processes on elements of the water cycle."[22] The science has evolved from one that simply indicated what minimum flows might be needed to maintain a particular species in a river, to one that recognizes the timing of flow is critical, or the fact that intermittent floods of a particular magnitudes are needed to maintain the most suitable river bottom and flood plain form for suitable habitat for native species, or to keep invasive species from becoming established. Furthermore, the physical process of water and sediment movement sets the stage over which is played a complicated set of interactions among the biota. Despite the progress that has been made in the past decade, considerable uncertainty remains about water use requirements for the environment.

With reduced flexibility in the water allocation system, supply shortfalls have become increasingly severe during drought periods—raising the costs of water access and threatening the integrity of aquatic systems. As demand for limited water supplies increase, the need for economic efficiency in water storage, delivery, treatment, and use becomes more critical.

Water rights and the laws governing them are the purview of the States but the laws of physics that dictate how much water is present in any given location, as well as where, when, and how water moves, are not constrained by political boundaries. Knowing how much water is available for use, and when water is available, are key for decision makers and the application of water laws. Yet "Many water sources have been over allocated because water rights were based on inaccurate predictions. One of the main contributors to inaccurate forecasting is the lack of data. Data on water supply and use are not readily available or aren't collected[2]." Furthermore, "Overuse of water sources is also aided by a lack of data. States often do not have information on how much water is extracted from sources, what pumping practices are used or how fast the water is recharged[2]."

An example of the need to know how much water is available comes from Albuquerque, New Mexico. In the 1950s several water-supply wells were pumped dry. Knowledge of the water resource available in the aquifer was rudimentary. Thus "What happened was that the city got a notice from its bank that its account was overdrawn and when it complained that no one could have foreseen this, only said in effect that it had no bookkeeping system[17]." The nation has no systematic process to track its water "accounts" or rates of use. This report proposes that the Federal science and technology community remedy this lack of fundamental resource information through a process of synthesis of the rich body of existing data using new methods of analysis, coupled with the application of new science and technology to fill critical information gaps and improve the accuracy of the assessments and forecasts.

In parts of the country, such as the Klamath Basin or the Missouri River, we are experiencing a kind of "gridlock" where there is intense competition among uses such as irrigation, navigation, municipal supply, energy, and ecosystem uses[18,19,20,21]. Much of our water-resources infrastructure was designed to minimize damage from excess water—floods, in addition to providing water for navigation, municipal supply, and energy; it was not designed for ecosystem water uses.

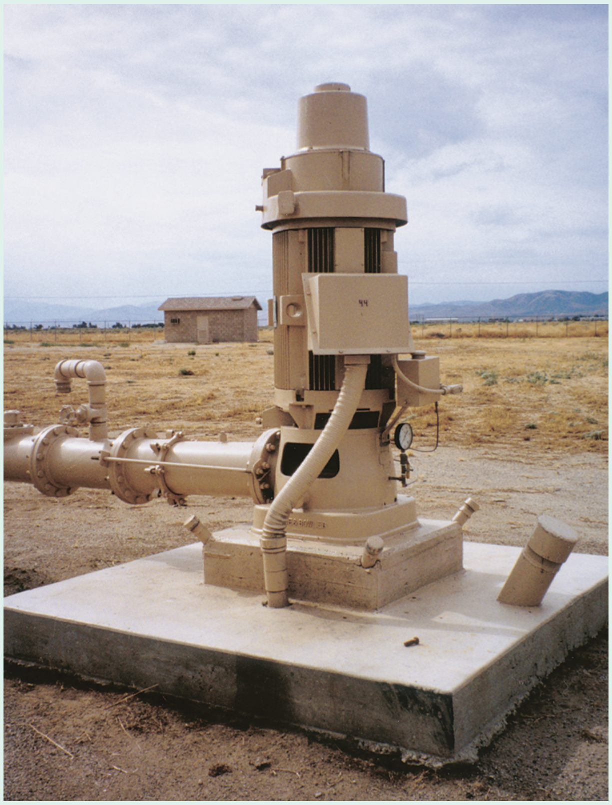
Quantification of ecosystem water use is a very difficult scientific problem (sidebar opposite). Until the question of the amount and timing of water needed for ecosystems can be resolved, these water needs will be ill-defined and needed investments and market decisions will be stalled; critical investments will be delayed and ecosystems will lack the appropriate level of protection. The science relating biota to water requirements needs to be pursued with vigor, to help break the gridlock, by providing information needed to answer the questions—how much water do the fish really need, or how much water is needed to maintain riparian ecosystems.

The institutions for water development and allocation have evolved with changes in social objectives, economic development, technology, and the degree of depletion of the resource. The key question for water manage-

Defining Water Use—Energy and Water

The agriculture and energy sectors are the two largest users of water in the United States[11]. Some of the water use is consumptive; water is lost through evapotranspiration from crops and fields or by evaporation from cooling. Some of the water use is non-consumptive; much of the water used returns to the source by irrigation runoff or from once-through cooling. When freshwater and saline water withdrawals for thermoelectric uses are combined with hydropower uses, the energy sector is clearly the largest water use sector, but it is also one of the least well understood. Application of new technologies to recycle water in power plants has resulted in substantial reductions in the amount of water withdrawn per kilowatt of electricity produced[11] (63 gallons per kilowatt-hour in 1950 and 21 gallons per kilowatt-hour in 2000). A very close linkage exists between the Nation's energy future and water future—water is crucial to the production of energy; different energy sources have different water needs. Conversely, many of the technologies for withdrawing, storing, or treating water consume large amounts of energy. Thus, the science of water availability and use is crucial to the planning of our nation's energy future. The reliability of both energy and water infrastructures are linked to competition among all water uses[24].

Conservation and use of water not thought to be a resource


US Geological Survey

Recharge pump, Antelope Valley, California

Water reuse and recycling are existing supply enhancing technologies. Also, a recent National Research Council report noted "some desalting technologies are now cost-competitive where source waters are brackish."[7] Desalination of water is often thought of in terms of obtaining fresh water from the ocean. However, ground water in some inland geologic formations also is brackish. The National Research Council report also indicated that "Because surface water storage opportunities will be far less attractive than they were in the past for reasons of cost and environmental impact, there will be pressure to develop additional storage capacity by utilizing underground aquifers."[3] Storage of surplus surface water in aquifers is accomplished either by direct injection or by channeling water to places where percolation of water into the subsurface is readily accomplished. This can deteriorate the quality of water in the aquifer, dissolve the geologic framework of the aquifer, or even cause clogging and reduced flow within the aquifer. Also, surface water placed within the aquifer does not remain stationary, as it would if held in surface storage behind a dam; the "bubble" of stored water can migrate[23] so recovery of the stored water can be problematic. It is not surprising then, that the National Research Council report[7] noted that "Substantive research is needed to address the practical problems of groundwater recharge and storage."

ment in earlier decades was: how much water can we take from this river? The new question is: How much water do we need to leave in the river and how will the development of the resource in the watershed and globally change the amount that the river will provide? The science needed to answer the new questions is very different from that which was needed for the questions of the past. When resources were relatively abundant compared to their level of use, the information needs were simple to satisfy. As competition for water intensifies the need for information becomes much more significant (sidebar previous page). More and more, water is becoming a marketed resource, with market trades taking place among users. Evaluation of the impacts of these market decisions demands a new scientific capability to help society avoid unintended consequences from these trades affecting other uses or users. Flexible resource management depends on comprehensive information about the resource.

In the past, planning estimates of future water use were taken as a given, based on projections of demographics and economics. Today we recognize that future rates of water use are based on social and technological choices. Our economy is remarkably adaptable. Farmers, ranchers, manufacturers, energy providers, and consumers will economize on their use of water. Science and technology is needed to widen the range of choices, provide users with information on the costs and benefits of these choices, and determine how information, incentives and new policies will facilitate wise use of our finite water resources (sidebar opposite). Thus, the needed science agenda is not only focused on physical and biological science, but social science as well[25,26].

What can current information tell us about water now and in the future?

Water use information has been collected and summarized at five-year intervals since 1950[11]. These data are from a variety of sources, public and private, sources other than Federal Agencies. These data can provide us with "nationally consistent, policy-relevant information on the status and trends of water use for the country."[3] However, improvements need to be made. These estimates also need to be integrated with study of water flow in surface water and ground water to understand the impact of water use on water availability in the future.

There are four difficult issues to resolve in the area of water use estimation:

- **Lack of coordination has resulted in use of different data standards.** The data are collected by many different agencies, with different definitions and laws governing what they do. Thus the data are third party information and thus present great difficulty in evaluation of their accuracy and bias. As a result data can not be effectively shared and integrated to support decision making.
- **Water use projections overestimate demand growth.** Projections of future water use have virtually always grossly overestimated the future growth in use[27] (page 46 of the United States General Accounting Office report)[1]. Water use has rarely included an ecosystem component in any kind of consistent way.
- **Relying on models and estimates rather than direct observation.** In many cases, some data, such as groundwater pumping, are not measured directly and have to be estimated indirectly.
- **Insufficient understanding of how people make decisions about water use.** There is a need to better understand the behavioral determinants of water use: how technology, information, adoption of new technology, market signals, and attitude, result in changed behavior.

Photo courtesy of US Department of Agriculture

Center-pivot sprinklers along the Columbia River near Hermiston, Oregon

Addressing weaknesses in water use information is one step to improve information for decision making about water availability. However, water use data also need to be integrated with surface and ground water flow information to understand the impact of water use on water availability in the future.

The National Research Council recently reported on the needs and approaches for improved water-use science, which relies on integration of multiple natural resource and economic information resources[3]. Without addressing the data issues identified above and improved coordination in technology and information about current and future water use, decisions about the future of water availability will be limited.

Demand for water resources is driven by social and economic factors that need to be measured and understood in order to make predictions about water demand, and about how to influence it. Further economic analysis can provide insights about how to promote development of new or improved technologies for water storage, distribution and their adoption. Water "use" is not simply a function of physical relationships, but is the result of behavioral decisions by households and by businesses, which can be influenced and changed through regulations, changing price incentives, penalties, and changing social norms. In some cases, rather than expanding sources of supply, the solution to meeting competing water demands (or conflicts) involves a change in water-management institutions that can yield voluntary or market-driven reallocations. The Federal Government has a role to play in documenting how such solutions can work, by tracking changes in water use patterns and the demographic and economic forces that have such a strong influence on water use. The Federal government, together with state and local governments, also plays an important role in ensuring water law and water rights are clear and readily enforceable.

Photo courtesy of USDA Natural Resources Conservation Service

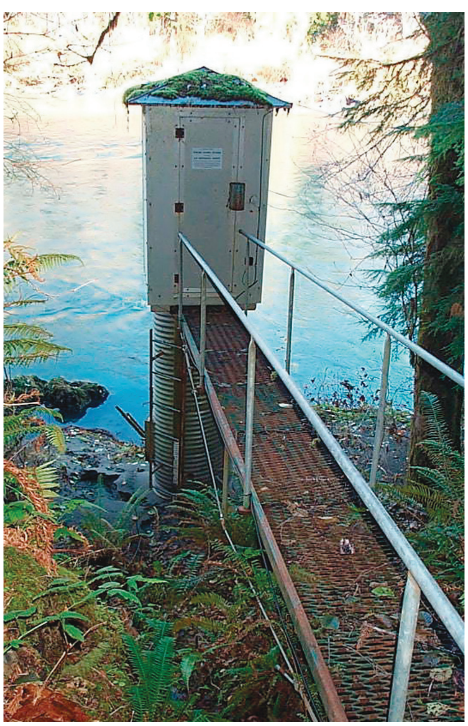
Irrigation field ditch, Idaho

What should we do?

The nation has no systematic process to track its water "accounts" or rates of use. This section identifies specific information needs of water managers and identifies steps that the Federal science and technology community in cooperation with partners can take to meet information needs.

Provide water managers with accurate information they need to make optimal decisions

- Decision makers need more accurate assessments of fresh water to enable them to set appropriate limits to the rates at which water is withdrawn from a given area, so that future generations have sources of water for drinking and other purposes.
- Water resource managers and water quality managers need information on the water needs of ecosystems and on the natural flows of rivers and aquifers, and their interconnection, in order to ensure flows that will protect species and whole ecosystems.
- Water resource decision makers need information about ground-water and surface-water linkages (both in terms of water quantity and water quality). These resources have been managed in the past as if they are separate resources, although use of one can affect the availability of the other. Separate management assures sub-optimal use of these resources.
- Public and private sectors need information on more efficient processes and methods for water use, reuse and recycling, so that all sectors can implement programs to reduce demand on existing water sources and on the infrastructure for both water supply and wastewater.
- Decision makers need water quantity information to enable them to make decisions regarding the protection of life and property in the event of river and flash floods.
- Decision makers need to plan at time frames of days to years, therefore improvements are needed to reduce (and accurately assess) the uncertainty of hydrologic forecasts in those time frames.


US Geological Survey

Hoh River gaging station, Washington

There are steps that can be taken to address water managers' decision-making needs. A United States General Accounting Office report[1] noted that water managers from 39 states identified expansion of the number of Federal data collection points as the most useful federal action that would help them meet their water management challenges. However, expansion of Federal data collection points alone will not provide us with a comprehensive understanding of water availability.

Many federal, state, and local agencies collect water information, but these efforts are not adequately coordinated to address priority needs of decision makers[1]. A recent United States General Accounting Office[1] report noted information on water availability is collected by the U.S. Geological Survey (streamflow, ground water), the National Weather Service (rainfall and snowfall), the Natural Resources Conservation Service (snow pack), the U.S. Department of Commerce's National Weather Service and U.S. Department of Agriculture's Natural Resources Conservation Service (water supply), the U.S. Bureau of Reclamation and the U.S. Army Corps of Engineers (reservoir water levels and flows), the National Park Service and U.S. Forest Service (streamflow that supplements U.S. Geological Survey information).

Additional information on reservoir water levels and flows in the Tennessee River Basin is available from the Tennessee Valley Authority. The Bureau of Indian Affairs also obtains information on water availability on tribal lands. States and other entities collect and share surface and ground-water data as part of studies done in conjunction with the U.S. Geological Survey[1]. The National Aeronautics and Space Administration provides additional capabilities to measure rainfall, soil moisture, atmospheric temperature and water vapor, surface temperature and snow cover, and potentially surface-water levels and changes in ground-water storage.

Improve use of existing assets for coordination of water information activities

There are two important assets for improving coordination of water information activities. The first is the Advisory Committee on Water Information, chartered under Office of Management and Budget Circular 92-01 to coordinate water data activities. The Advisory Committee on Water Information has played an important role in bringing together federal agencies and their state, local, academic and private sector partners to coordinate water information activities. Advisory Committee on Water Information coordination across agencies and layers of government is critical to improving understanding of water availability and use.

The second coordination asset is use of the internet and data sharing technologies. By making data easy to access, integrate and apply through the internet, all parties involved as producers and users of water information can improve decision making. Use of latitude and longitude, and hydrologic accounting units[28] as a common reference for water data is an important aid for data access and integration.

Data collected by the various entities and agencies need to be synthesized in a systematic way for the major river basins and aquifers of the United States. Although these data are not all collected for the same purpose by the various agencies, they do provide a framework for examining how much water is in surface and subsurface storage as well as how much water is moving between the atmosphere, land surface and ground water at small watershed, basin, and aquifer scales. These data need to be synthesized through the use of models to evaluate the changing status of our nation's water "accounts" and to facilitate the prediction of future conditions.

Water Resources Regions and hydrologic accounting units of the United States[28]

Improvements are needed in the basis for decisions about water

One of the challenges facing the nation, according to a report by the National Research Council[15], is the need to "establish the capacity for detailed, comprehensive hydrologic forecasting, including the ecological consequences of changing water regimes, in each of the primary U.S. climatological and hydrological regions." The importance of having such hydrologic forecasts is demonstrated by the case of the Yakima River in the State of Washington.

Apple and pear orchards near Yakima, Washington

Photo courtesy of US Department of Agriculture

In early 1977, a forecast for the Yakima River Valley in Washington State indicated that amount of water available during the irrigation season would be half of the long-term average[5]. Drought had been experienced in western states in 1976 and 1977 loomed as another drought year. It was expected that there would not be enough water in 1977 for all of the users in the basin[5]. On the basis of the forecast of water availability, orchard owners leased water rights from those irrigators with senior water rights. Some farmers transplanted crops to other basins. Four hundred irrigation wells were installed at an estimated cost of $9 million. Ranchers sold off livestock. However, by May more water was available than had been projected, due to the return of more typical amounts of precipitation. The inaccurate forecast of water availability resulted in significant economic consequences for water users in the basin[5].

This example highlights the economic importance of accurate forecasts over time frames of weeks to months. Similarly, it is crucial for planning to have robust methods for forecasting future hydrologic conditions on time scales of years to decades. The infrastructure to store, deliver, and use water was built during some particular former climate condition which may not provide an appropriate basis for future planning. Hydrologic and atmospheric science must find the means to objectively consider natural climatic shifts such as have been observed in the past or current climate variability, such as is now occurring, which have decreased the size of snow packs in many river basins due to decreased snow fall and earlier snow melt[14].

Create a common watershed-based framework for coordinating federal efforts to assess water availability and use

The nation can be divided into 21 Water Resources Regions (figure opposite). Even though major aquifers cross boundaries of these regions, such a starting point provides a readily recognizable framework for the layperson and water managers. As a first step, it would be useful to determine if there is one, or perhaps two of these regions in which existing data from the various entities and agencies could be combined to provide a comprehensive indication of water availability and use within the basin. An arid basin and a humid basin might be two places to start, for example. This would span the range of measurements from point measurements on the ground to measurements from space. Such a pilot project would serve to show what interagency cooperation is needed, as well as the technical challenges of combining data from various sources into a meaningful assessment of water availability. The resulting water resources information summary could provide a benchmark against which emerging science and technologies could be evaluated, such as the nascent U.S. Integrated Earth Observation System[46]. The water resources summary might also identify information gaps that need to be filled as well as the reality about the uncertainties in our ability to account for all the water in a basin.

Analysis of a Water Resources Region should also be the focus for the best possible determination of water use, using scientifically credible accounting and statistical determination of error. Within a Region evaluation of water alternatives to make more efficient use of water could simultaneously be examined. Also, assessment of the current status of water availability and use in a Water Resources Region would serve as the foundation for detailed, comprehensive hydrologic forecasting. The summary of water resources in the Region should be revisited on a 5-year interval against which forecasts of water availability and use could be evaluated and refined.

Over the past 25 years considerable progress has been made in the science and technology available to assess the water resources of a basin, aquifer or Water Resources Region. These include the use of technologies such as acoustics, radar, microgravity, and geochemical and isotopic tracers and the advances in science that have made their use possible. What is needed now is to apply these technologies to the assessment and forecasting of conditions over entire watersheds and aquifer systems. To do so would be a major first step in improving our understanding of the nation's water resources.

Government and the private sector need a sound understanding of water availability and use to make good decisions that provide water for future economic activity and environmental protection. The role of the federal science agencies is to produce the needed data, understanding predictive tools, and synthesis of national and regional water conditions to form a sound basis for public and private decisions about water (sidebar, previous page).

Photo courtesy of USDA Natural Resources Conservation Service

Sprinkler irrigation, Yuma, Arizona

Knowledge gaps related to water availability and use

Improved applications of currently available science and technology are one aspect of addressing current water shortages and the need to increase water availability. While assessing current information by Water Resources Regions is a necessary first step, addressing other science and technology gaps could help improve the accuracy of current and future assessments of water availability and use. In addition, science and technology could also play a significant role in increasing the availability of water through technological achievements in water conservation and the efficiency of consumptive water uses. While many gaps are identified, such efforts should be prioritized by the likelihood of increasing the accuracy of current and future water availability and use assessments, as well as relevance to decision making needs. Science and technology knowledge gaps are listed under categories based on questions that need to be answered by water managers.

Needed improvements in data that define the available resource

- Improved methods for predicting streamflow at time scales of hours to seasons, to enhance the effectiveness of water management decisions.
- Improved methods for characterizing and predicting a river's natural flow regime—its characteristic pattern of flow quantity, timing, and variability[29, 30].
- Improved methods for tracking changes in the storage of surface waters.
- Improved methods for tracking changes in the storage of water as ice and snow, such as by remote sensing using microwave radar[31].
- New methods for estimating changes in storage of ground water, such as use of microgravity measurements on the ground and from space[32, 33], and improved understanding of recharge of the nation's aquifers[34].
- Renewed synthesis and collection of ground-water resources data on the regional and national scale through process-based regional assessments of the nation's ground-water resources[35]. Organizing available information on changes of ground water in storage, similar to what has been done recently for the High Plains Aquifer[16]. (sidebar, page 2)
- Improved data standards and analysis methods, including validation of data entered into Geographic Information System data bases, to examine trends in water data, support water source development, water quantity production, prediction of future areas of concern, and potential water management issues.
- Improved data management and synthesis to integrate remotely-sensed and insitu data across all scales, such as envisioned in the developing U.S. Integrated Earth Observation System[46].

Photo courtesy of US Department of Agriculture

Data from a solar-powered precipitation gauge is used to develop models to forecast water supplies from snowmelt in the Owyhee Mountains, Idaho.

Needed improvements in understanding the links between surface water, ground water, the ocean, the land surface, and the atmosphere

- Improved methods for measurement of streamflow[36], such as increased use of acoustic Doppler velocity meters and radar, and improved analysis of the changes in flow and incorporation of these hydrologic fluxes of surface and ground-water in coupled atmosphere—ocean—terrestrial models used to predict weather and climate[37].
- Improved understanding and methods for estimating the hydrologic characteristics of agricultural irrigation, including: water consumption from source waters, runoff, returns to surface waters, and recharge of ground water, as well as the effects of large-scale irrigation on local weather patterns.
- Improved understanding of the connections between oceanic circulation phenomenon, such as the El Niño Southern Oscillation or Pacific Decadal Oscillation and the North Atlantic Oscillation on continental weather and hydrologic characteristics, in order to improve seasonal hydrologic forecasting.
- Improved methods of measuring precipitation, streamflow, and potential evapotranspiration[38].
- Use of new technologies to determine regional scale fluxes of water from the landscape to the atmosphere through evapotranspiration, such as by use of Advanced Very High Resolution Radiometry from satellite observations and linking such observations to ground-based eddy correlation measurements[39].
- Improved descriptive (simulation) and predictive (forecast) models that link ground water and surface water[40,41]. Decision makers are faced with the challenges of managing these water resources in the short term, even though the effects on ground water can persist for long periods, and among States whose laws may treat these as separate resources[42].

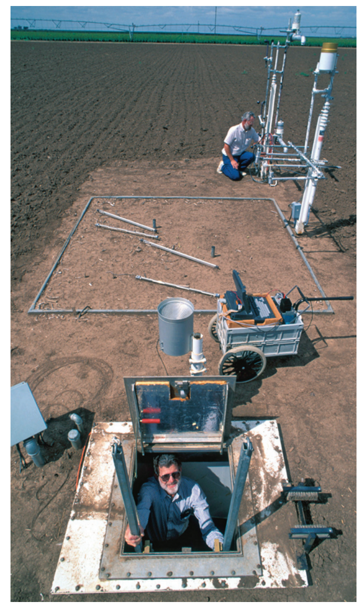
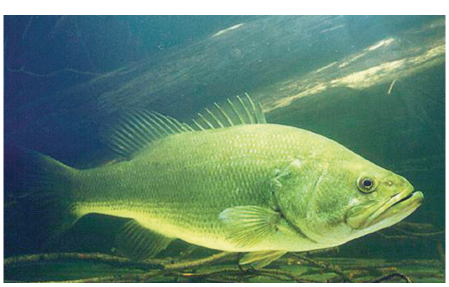


Photo courtesy of US Department of Agriculture

Soil scientists conduct bare soil evaporation experiments in the area west of the Texas High Plains in order to predict a crop's rate of water use.

Needed improvements in defining ecosystem water needs



Gene Hester

- Improved methods for predicting the responses of biological communities to changes in flow, temperature, clarity, chemistry, and various other determinants of habitat condition.
- Improved understanding of ecosystem structure, function and response to changes in aquatic regime and habitat. (sidebar, page 4)
- Improved methods for predicting future changes in storage (given predicted changes in land and water use) and predicting how these changes in storage will affect rate, temperature and chemistry of streamflow, as well as how altered streamflows affect the physical structure of the downstream habitat.
- In order to understand the ecological consequences of altered water availability, we need information and synthesis in fields of physiology and population biology, as well as advanced modeling capabilities about biodiversity in relation to hydrologic conditions.

Needed improvements in defining water use

- Improved methods for estimating current water use[43] and forecasting future water use in light of changes in technology, economic conditions, attitudes, and legal and political changes is needed to ensure adequate water supply. These methods should include both consumptive and non-consumptive uses, such as transportation on inland waterways.
- A comprehensive assessment of the energy demands for water is needed to provide a better basis for national energy planning, water resource allocation, and technology development. Such an assessment would include comprehensive assessments of data needs and regional assessments of water use in the energy sector in all parts of the United States. (sidebar, page 5)

Needed improvements in conservation and use of water not thought to be a resource

- Improved supply-enhancing technologies for water conservation of good quality waters.
- Improved supply-enhancing technologies aimed at better utilization of waters of impaired quality, including saline waters, or for storing water from periods of water surplus for use during periods of deficit. (sidebar, page 6)
- Improved understanding of inadequate or leaking water-supply infrastructure that could affect availability and use.
- Improved understanding of the processes that can affect the utility of storing water in aquifers by artificial recharge, including aquifer storage and recovery[23].
- Improved understanding of the hydrogeologic and geochemical characteristics of aquifers containing brackish and saline ground-water resources that could provide fresh water through desalination.

California Department of Water Rsources

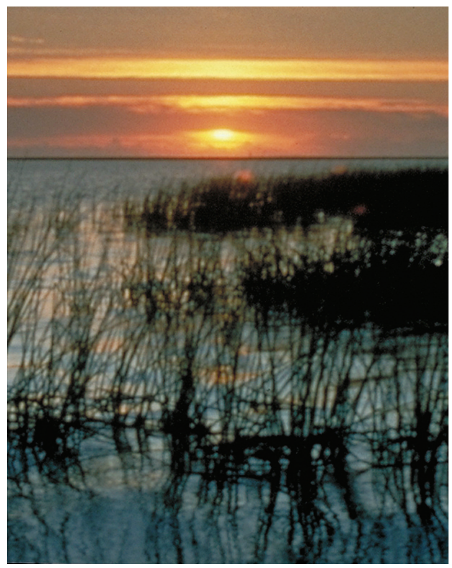
Pumping groundwater for irrigation in the SanJoaquin Valley, California

Needed improvements in understanding of the inherent variability of our water resources

- Improved ability to make meaningful probabilistic forecasts at time scales of hours, days, or months.
- Improved understanding of the relationship of climate variability and change to changes in hydrologic variables (streamflow and ground water recharge) in order to improve long-range water resource planning. (sidebar, page 11)
- Improved drought/impending water crisis forecasting and prediction capabilities, including placement of current conditions in historical context with existing long-term data or proxy information from tree rings, ice cores, or sediment cores from lakes/wetlands. Recent widespread drought in 2002 and the Mississippi Flood of 1993 are reminders that decisions about water resources are made within a natural framework of considerable variability[14, 44].
- Improved understanding of the cumulative effects of water management decisions on aquatic ecosystems, water supply infrastructure, as well as energy supply infrastructure.

Summary

Water managers and decision makers increasingly need to understand the supply and demand for fresh water in the United States, to assess current and anticipated surface water and ground water resources, and to balance competing demands for water for human and environmental uses. This report describes high-priority science and technology efforts needed to improve the information base for decision making on these issues. Improved information for water assessment and management will require coordinated research, monitoring, and information sharing among Federal, state, and local agencies.



US Geological Survey

Answering the question

"Does the United States have enough water?"

"National water availability and use has not been comprehensively assessed in 25 years."
— U.S. General Accounting Office report, July 2003[1]

A comprehensive assessment of water availability and use, including examination of trends related to both, is overdue.

Water "…conflicts are occurring within states, among states, between states and the federal government and among environmentalists and state and federal agencies."
— Council of State Governments report "Water Wars", 2003[2]

Without quantifiable and scientifically defensible estimates of environmental water requirements, water gridlock—intense competition among irrigation, navigation, municipal supply, energy, and the environment—is unlikely to be resolved.

"In this new century, the United States will be challenged to provide sufficient quantities of high-quality water to its growing population."
— National Research Council Report, 2001[7]

Some waters are not considered to be a resource, yet should be . Further research and development about water reuse, desalination, aquifer storage and recovery may provide ways to meet the challenge of providing high-quality water to our citizens.

"Efforts to conserve water—from low-flush toilets to more efficient power plants and crop irrigation—are working so well that Americans use less of it than they did 30 years ago."
— U.S.A. TODAY March 11, 2004[45]

The socioeconomic factors that determine water use are not fully understood. Yet, those factors will be a key to getting the most benefit from available and emerging water-saving technologies.

"Decisions about use of our water resources can result in severe economic or environmental consequences when the decisions are based on poor information about water availability and use[4], or on badly flawed forecasts of future availability[5]."
— This report

Planning and efficient operation of water infrastructure depend on water forecasts that are valid over times of hours to months. Water managers need improved river forecasts, including recognition of the role of ground water in those forecasts.

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