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Report to the Chairman, Subcommittee on Oversight and Investigations, Committee on Energy and Commerce, House of Representatives

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WATER RESOURCES

Federal Efforts to Monitor and Coordinate Responses to Drought

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Resources, Community, and
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The Honorable John D. Dingell
Chairman, Subcommittee on Oversight
and Investigations
Committee on Energy and Commerce
House of Representatives

Dear Mr. Chairman:

This report responds to your request on how federal agencies monitor and coordinate the government's response to drought. As agreed with your office, we reviewed (1) the data gathered and used by federal agencies to report drought conditions and (2) the past and current federal mechanisms to plan, monitor, and coordinate the government's response to drought.

Three federal agencies are primarily responsible for collecting the data that are used by other federal, state, regional, and local agencies to monitor the condition of water resources. A number of other federal agencies, primarily the Department of Interior's Bureau of Reclamation and the U.S. Army's Corps of Engineers, have responsibilities in developing and managing water resources, in cooperation with other federal agencies, state governments, interstate commissions, local governments, and other entities with water-related missions. These agencies usually also cooperate with the agencies responsible for collecting the data.

Results in Brief

Collecting and reporting data on drought conditions in the United States is a collaborative, multilevel effort led by the federal government. State and local governments make important contributions of work and funding to this effort. Federal, state, and other users are generally satisfied with the data on drought that are collected and/or distributed by federal agencies.

No permanent federal organization is responsible for monitoring drought conditions and planning the government's response to drought. Instead, individual agencies carry out these activities and make various arrangements to cooperate with one another. When drought has been severe or has had widespread geographic impact, such as droughts in the West, the Midwest, the South, and California within the last 20 years, temporary federal interagency committees have been set up to coordinate

the response. However, because drought periodically has had more and more significant impacts on large areas and segments of the economy, temporary committees may no longer be able to do the long-term planning needed for such droughts, promptly resolve policy differences among federal agencies, or coordinate the federal response to drought.

Background

A drought occurs in at least part of the United States almost continuously and frequently affects broad geographic areas. A drought can occur in areas of high as well as low rainfall because it is measured relative to some long-term average or "normal" condition to which local activities and the environment have adapted over a long period. For example, the normal rainfall in a semiarid region like southern California would be considered a drought in the temperate rain forests of the Pacific Northwest.

Despite existing water projects, the demand for water resources has increased, and a major drought in this country affects many people. For example, the 1976-77 drought created serious water shortages for two-thirds of the nation and was particularly severe in the West. In 1988, the nation experienced a severe drought extending from California to the Pacific Northwest/Northern Rockies to the Upper Midwest and south to Georgia, devastating spring and summer crops in the Midwest and affecting waterborne traffic on the Mississippi River. Drought also occurred for several years in the Southeast, including the Savannah River Basin. California experienced 6 straight years of drought through 1992, which tightened water supplies available for agriculture, cities, and environmental needs, such as for wildlife and water quality. However, heavy snow and rain in the winter of 1992-93 have eased the water shortage there. As these recent examples illustrate, major droughts occur periodically in areas across the nation and are likely to occur again, creating impacts that may significantly change the way we live.

To deal with the increasing demands on water in the West, including the impacts of drought, and with the diverse authority over federal water policy, the Western Water Policy Review Act of 1992 (Title XXX, P.L. 102-575, Oct. 30, 1992) directed the President to undertake a comprehensive review of federal activities in the 19 western states, including Alaska and Hawaii, that directly or indirectly affect the allocation and use of water resources.

Data for Monitoring Drought

Because there is no standard definition of drought, many factors are monitored to indicate drought in various contexts. Three federal agencies are the primary collectors of these data, which they obtain directly or through the cooperation of many other federal and nonfederal agencies.

Drought is defined in different ways for different activities or impacts. There are meteorological, agricultural, hydrologic, and socioeconomic droughts, all relating to a shortfall in water supply. The data used to indicate drought conditions vary according to the definition and may include precipitation (including snowpack), temperature, streamflow, groundwater level, soil moisture, and reservoir and lake levels. These data are used or analyzed to forecast and monitor water conditions.

Federal Agencies That Collect Drought Data

Various federal agencies measure and monitor aspects of the water cycle in accordance with their traditional responsibilities and/or needs in carrying out their water-related missions. The three primary federal drought data collectors are the Department of the Interior's U.S. Geological Survey (USGS), the Department of Commerce's National Weather Service (NWS), and the Department of Agriculture's Soil Conservation Service (SCS). Although each agency has a unique mission, all three agencies have overlapping data needs and share much of the information or collect data on a cooperative basis.

USGS is the lead federal agency operating the Water Information Coordination Program, whose mission is to identify opportunities to make the best use of federal agencies' resources for water information. Under this program, USGS chairs the Interagency Advisory Committee on Water Data to promote communication and collaboration and to ensure cooperation among the agencies. USGS staff said that about 30 federal agencies[1] participate on the committee either as data providers or as data users.

With help from state and local governments and other federal agencies, USGS systematically collects data needed to determine and evaluate the quantity, quality, and use of the nation's water resources. It also analyzes the data and conducts research on water-related natural hazards, such as drought and floods. The data and analyses are disseminated through reports, maps, and computerized information services.

[1]An agency is defined as a major organization within the federal government below the department level.

In addition to performing its well-known roles—forecasting the weather and river conditions—NWS monitors drought conditions and issues drought advisories. The analytical and forecasting work is based on data collected directly by NWS or obtained from other federal and nonfederal sources.

SCS conducts the cooperative snow survey program in the 11 western states that rely on snow melt as their primary source of water. The state of California runs an independent program that shares data with the federal program. The information, which is collected automatically by a radio system and manually by snow surveyors, is translated into local water supply forecasts that the state SCS offices issue monthly from January to June in cooperation with NWS. Major sectors of the western economy, such as agriculture, industry, and recreation, base their plans on these forecasts.

Other agencies—such as Interior's Bureau of Reclamation (the Bureau), the Department of the Army's Corps of Engineers (the Corps), and state agencies—cooperate in collecting data and are among the principal users. These agencies conduct their own analyses of data and in some cases publish them in the form needed by the agency and its constituencies.

The data gathered by the three principal federal data-collecting agencies are used and reused for analyses and overviews of water and weather conditions tailored to particular types of users, such as agricultural interests, government agencies at all levels involved with water and other natural resources, water project operators, weather observers, and scientists. Many of the data are used, analyzed, or reprinted by more than one agency through cooperative data-sharing programs.

Views on Data Quality

Our interviews with federal, state, and other users of data collected by federal agencies showed they were generally satisfied with the data on water resources and drought. NWS and USGS staff said that the principal way to improve their results would be to increase the number of data collection points or the technology used in the various networks they run. In addition, certain users said that changes in methods of reporting and analyzing data could make the data more useful for their purposes. An effort is under way to provide historic data on the frequency of drought.

In general, USGS officials told us that the data they produced were of good quality. They said, however, that there are limitations in the number of data-collecting stations, such as the gauges measuring streamflow, and on

their control over the quality of the data provided by cooperating nonfederal agencies.

NWS officials said that the reliability of longer-term forecasts of temperature or precipitation ranges and of streamflow is limited and that improvements in accuracy depend on advances in science and improvements in technology such as automated remote sensors, super computers, and advanced radar and satellites. These officials pointed out that the current analysis and translation of raw data into reports on current conditions and forecasts depends on the professional judgment and experience of meteorologists rather than on strictly computer outputs. They said that because data are limited, conditions are reported very generally and the reports may not be valid for local areas.

Both the Corps and the Bureau favored improvements that would increase the accuracy of measurements, such as additional gauging stations to provide more data. They and the Department of Agriculture noted the limited usefulness of longer-term weather forecasts for anticipating drought conditions and planning a response.

To meet the needs of regional drought planners for accurate, consistent historical precipitation, streamflow, and other data to measure the probability of drought across the nation, three federal agencies are cooperating to produce a drought atlas. The Corps of Engineers is leading this effort under its national drought study, and USGS and the National Climatic Data Center of the National Oceanic and Atmospheric Administration are performing analyses for the atlas. The planned drought atlas will provide probable frequencies for droughts lasting from 1 month to 5 years and give a rational basis for managing water during drought, Corps staff said. (App. I contains additional details on these matters.)

Federal Coordination of the Monitoring of and the Response to Drought

No permanent federal organization is responsible for monitoring and planning for drought or for coordinating the federal response to drought. Instead, these activities are normally carried out by individual federal agencies, which make various arrangements with one another to cooperate and share data when required. Temporary interagency committees at the federal level have been set up to coordinate the response to major droughts during the past 20 years.

The Water Resources Council was established in 1965[2] to facilitate interagency planning and policy coordination among the various federal water programs. While the Council undertook few activities specifically related to drought, current federal officials and former Council staff said that the Council's general water resources planning and coordination activities had assisted past responses to drought. The Council was, however, generally limited in its ability to coordinate and shape policy because it had to achieve its results through the voluntary actions of the federal agencies involved. In 1981, the administration proposed to eliminate the Council because it was not cost-effective and because the administration wanted the Cabinet to handle this function. The bulk of Council funding was cut off on October 1, 1982.

Temporary Interagency Committees

For the 1976-77 drought across two-thirds of the nation, the 1988 drought in the central United States and other areas, and the 6-year drought that has recently abated in California, federal interagency committees or task forces provided forums for policy development and coordination. All of these droughts were serious and had widespread impacts. Participants on the committees and task forces generally reported that these efforts increased communication and provided contacts while their agencies responded to drought impacts and recommended emergency drought response legislation to the Congress.

We reviewed the workings of the Federal Interagency Task Force on the California drought in detail and the activities of the prior two committees by examining published reports and interviewing participants. The California task force was established in January 1991 by the Secretary of the Interior at the request of the White House staff as California entered its fifth year of drought. The task force's purpose was to enhance communication among the agencies and to produce a list of assistance available from federal agencies. Participating agencies included the Departments of the Interior, Agriculture, Commerce, Justice, and the Treasury; the Army Corps of Engineers; the Federal Emergency Management Agency; the Council of Economic Advisers; and the Office of Management and Budget.

The California task force consisted of seven subcommittees, whose chairs and vice chairs met periodically to exchange information on their projects, programs, and water conditions, highlighting issues affecting the response to the drought in California. For example, implementation of the federal

[2]Water Resources Planning Act of 1965 (P.L. 89-80).

Endangered Species Act to protect the habitat of migrating salmon affected the allocation of the scarce water between in-stream uses, such as for fish, and off-stream uses, such as irrigation, served by state and federal water projects. The task force also heard reports on the status and content of legislative proposals for drought relief. Participants said the main benefit of the task force was better communications. The task force also provided a ready list of contacts for obtaining information and cooperation from headquarters staff in the relevant agencies.

Recent studies have discussed the need for an interagency body or committee to coordinate the monitoring of conditions and/or to plan and oversee the federal response to drought. Particularly sensitive issues needing interagency coordination arise when federal law and agencies' policies produce conflicts in water allocation decisions during severe drought. Recent droughts affecting the Missouri River, the Savannah River, and California have all produced such conflicts.[3] Such conflicts have included the need to set priorities and make trade-offs among various water users to meet the needs of recreation interests, water users, navigators, water quality, hydroelectric power generation, and fish and wildlife.

As part of its study of water management during drought, the Corps held three major workshops involving federal, state, regional, and university representatives. There was general agreement that the country would benefit from better coordination during drought. The Corps' study noted that interagency planning and coordination bodies at the national level had disappeared, but it also noted that the need for such mechanisms was as strong as it had ever been. The Western Governors' Association in 1989 called for a White House group to help improve coordination among federal entities and with states broadly on water resource issues, including drought. The association cited federal water policies that lacked guiding principles, which result in redundance, turf battles, and delays.

Planning for Drought

While the Corps and the Bureau may consider the impacts of drought on project operations during their initial development of new water projects, specific contingency planning for drought is a relatively new exercise for the Corps and recently was permanently authorized for the Bureau.

[3]See Water Resources: Corps of Engineers' Drought Management of Savannah River Projects (GAO/RCED-89-169, June 12, 1989) and Water Resources: Corps' Management of Ongoing Drought in the Missouri River Basin (GAO/RCED-92-4, Jan. 27, 1992).

As of September 30, 1992, the Corps had completed drought contingency plans for the 334 projects requiring them. The Reclamation States Emergency Drought Relief Act (P.L. 102-250, Mar. 5, 1992) authorized the Secretary of the Interior to conduct drought contingency planning for the prevention or mitigation of adverse effects of drought in consultation with appropriate federal and state officials; Indian tribes; and public, private, and local entities. The additional authority was needed to plan some drought relief actions that go beyond the service areas and functions authorized for Bureau projects. At the state level, nearly half of the states have an overall drought response plan and/or are monitoring drought.

Western Water Policy Review Authorized

The Western Water Policy Review Act of 1992 mandated that the President, assisted by an 18-member advisory commission and staff, make a broad review of federal activities and policies that affect the allocation and use of water resources in the 19 western states, including Alaska and Hawaii. In reporting on the legislation on the proposed study, the Senate Committee on Energy and Natural Resources cited the significant demands on water created by drought as one of the factors creating the need for a review of the adequacy and effectiveness of current policies and institutional arrangements to address western water problems.

The President is to report to the Congress by October 30, 1995, on his findings and any recommendations. The commission is to be composed of the Secretary of the Interior or his designee, the Secretary of the Army or his designee, a Western Governors' Association representative, a western tribal governments' representative, six other appointed members, and 12 ex officio members from the Congress. Department of Interior staff reported that the new administration's appointments to the advisory commission were still pending as of May 4, 1993, and that $2 million in funding was requested in Interior's fiscal 1994 budget for the commission to begin work. (App. II contains additional details on these matters.)

Conclusions

Users are generally satisfied with the collection and dissemination of data by federal agencies to monitor drought conditions. Although several agencies are involved, interagency cooperation in data collection programs and in the sharing of data meets most needs. Interagency coordination of the recent federal response to drought has also proved to have useful, positive results. However, the extent to which a federal committee, especially a temporary one, can bring about improvements in monitoring and in planning and coordinating the response to severe

drought depends on the voluntary participation of responsible departments and agencies. Past experience with a permanent water resources policy organization—the Water Resources Council—suggests that progress on important interagency policy questions is difficult to attain when it depends on voluntary action.

The Congress premised the Western Water Policy Review Advisory Commission's mandated study, in part, on concern about the diverse federal authority over water policy. The commission will be in a position to review, in addition to the mandated issues, the issue of whether a permanent mechanism is needed to improve the ongoing planning and coordination of the federal response to drought. As we have reported, drought can and does occur all across the United States, and the federal government must respond in all areas. Accordingly, the mandate provides an opportunity for a study of a federal coordination mechanism for drought in the West that could also have applicability to the federal response to drought in the East.

Matter for Congressional Consideration

Because the Western Water Policy Review Advisory Commission is to review federal water activities affecting the western states and is to consider whether reorganization or consolidation should be proposed for water resources development and management agencies, the appropriate committees of the Congress may wish to request that the commission consider whether a permanent mechanism is needed to monitor drought and to plan and oversee the federal response to severe drought. The commission could also be requested to consider whether such a mechanism should have authority to resolve policy differences among federal agencies.

Agency Comments

We discussed the results of our work, including the facts contained in this report and the implications of these facts, with the following senior officials and their staffs, who provided views on behalf of (1) Interior: Chief Economist of the Contracts and Repayments Branch in Bureau headquarters; (2) the Army: Deputy Chief of the Policy and Planning Division in the Corps' Directorate of Civil Works; and (3) Commerce: Deputy Assistant Administrator for Weather Services, National Oceanic and Atmospheric Administration. They generally agreed with the facts as presented. We incorporated, where appropriate, their technical clarifications and corrections and comments on the data and interagency

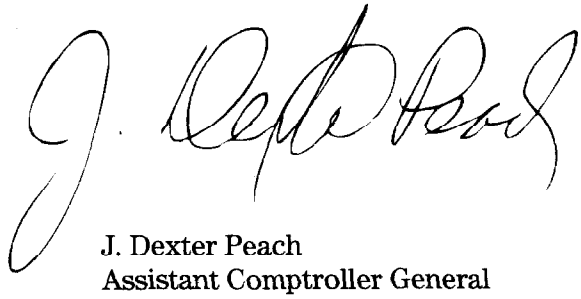
coordination issues raised by the facts. However, as requested, we did not obtain written agency comments on a draft of this report.

To develop the information contained in this report, we interviewed officials from the various federal agencies involved in collecting data and reporting water conditions, as well as officials involved with past interagency coordination committees. We also spoke with state water resources officials in Pennsylvania and Colorado, which were judgmentally selected as examples of eastern and western states. We also interviewed officials of various national, regional, or state organizations involved with water resources. We reviewed studies and other literature relating to federal drought management, as well as records maintained by federal and state agencies. We conducted our review between March 1991 and December 1992 in accordance with generally accepted government auditing standards. (See app. III for details of our objectives, scope, and methodology.)

As arranged with your office, unless you publicly announce its contents earlier, we plan no further distribution of this report until 30 days after the date of this letter. At that time, we will send copies to interested parties and make copies available to others on request.

The report was prepared under the direction of James Duffus III, Director, Natural Resources Management Issues, who may be reached at (202) 512-7756 if you or your staff have any questions. Other major contributors to this report are listed in appendix IV.

Sincerely yours,



J. Dexter Peach
Assistant Comptroller General

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Abbreviations

CFC	chlorofluorocarbons
NWS	National Weather Service
NOAA	National Oceanic and Atmospheric Administration
RFC	River Forecast Center
SCS	Soil Conservation Service
USDA	U. S. Department of Agriculture
USGS	U. S. Geological Survey
WRC	Water Resources Council

Federal Data for Monitoring Drought Conditions

Collecting and reporting data on drought conditions in the United States is a collaborative, multilevel effort led by the federal government. State and local governments make important contributions of work and funding to this effort. Federal, state, and other users are generally satisfied with the drought data that are collected and/or distributed by federal agencies, although some users or data collectors believe that more data and improved data reporting and analysis would make the data more useful in planning for and managing drought.

Many Definitions of Drought

Several types of data on water resource conditions may indicate lack of moisture. Whether the data indicate a drought, however, depends on the definition of drought used. The significance of various measurements—of precipitation, temperature, streamflow, groundwater, soil moisture, reservoir levels, or snowpack—in indicating a drought depends on local conditions and their impacts on the user or activity.

A study by the Department of Army's Corps of Engineers (the Corps) has defined drought as

> the condition of widespread and negative economic, social and, environmental impacts because there is less water than expected. The shortfall can come from a lack of precipitation and/or a deficiency of water in storage, a problem with the distribution systems, or the inefficient use of water.[1]

The Corps pointed out that the operational definition of drought to trigger the legal authority for a response is when previously agreed-upon conditions, which are limited and regionally specific, have been met. The Corps said the majority of their projects use the lowering of reservoir water volume to some predetermined below-normal level to trigger operation under drought plans.

Officials from the Bureau of Reclamation (the Bureau) told us that the operational definition of drought depends on the individual water projects and the particular storage levels and projected inflows that trigger a drought response. The Bureau's overall definition of drought is "an extended climatological condition resulting in less than normal water supply for a specific area and time period."

[1]The National Study of Water Management During Drought: Report on the First Year of Study (Fort Belvoir, VA: U.S. Army Corps of Engineers, Institute for Water Resources, May 1991), p. 1.

A drought can occur in areas of high as well as low rainfall because it is relative to some long-term average or "normal" condition to which local activities and the environment have adapted over a long period. For example, the normal rainfall in a semiarid region like southern California would be considered a drought in the temperate rain forests of the Pacific Northwest.

According to an academic analysis, drought falls into one of four categories: meteorological, agricultural, hydrologic, or socioeconomic.[2]

- A meteorological drought is generally defined by the degree of dryness and the duration of the dry period. It is often specific to geographical areas and related to a long-term average or normal precipitation. The conditions that result in meteorological drought are highly variable around the world.
- An agricultural drought occurs when meteorological drought affects crops. Various meteorological factors, such as shortages of and departures from normal precipitation, may be linked to the needs of crops in an agricultural drought.
- A hydrologic drought involves the impact of dry spells on the circulation of surface and subsurface water, usually in a particular basin, and has a particular duration and severity. Hydrologic drought may continue to occur when meteorological or agricultural drought has subsided.
- A socioeconomic drought usually involves agricultural, meteorological, or hydrologic factors that are associated with the supply and demand of some economic good. An example is a shortage of water to meet the demands of human activities, such as agriculture or other economic development, which exceed the available water supply.

According to the National Weather Service's (NWS) Office of Hydrology, existing knowledge and technology cannot be used to forecast the onset or extent of a drought because the beginning of a drought is ill-defined and slow to develop. The climate parameter important in the development of a drought—below-normal precipitation—is difficult to predict. Ongoing monitoring of weather, hydrologic, and agricultural conditions eventually indicates drought at some time after it begins.

Federal Collection of Drought Data

The primary federal collectors of drought data are the Department of Interior's U.S. Geological Survey (USGS), the Department of Commerce's NWS, and the Department of Agriculture's Soil Conservation Service (SCS).

[2]Donald A. Wilhite and Michael H. Glantz, "Understanding the Drought Phenomenon: The Role of Definitions," Planning for Drought: Toward a Reduction of Societal Vulnerability, ed. Donald A. Wilhite, et al, (Boulder, CO: Westview Press, Inc., 1987), p. 14.

Each has a unique mission, but the three agencies' needs overlap, and many data are shared or collected cooperatively. The following sections describe these agencies' needs for and activities to collect water resources data.

U.S. Geological Survey

The mission of USGS' Water Resources Division is to provide the hydrologic information and understanding needed for the best use and management of the nation's water resources. In cooperation with state and local governments and other federal agencies, USGS systematically collects data needed for determining and evaluating the quantity, quality, and use of the nation's water resources. It also analyzes the data and conducts research on water-related natural hazards, such as drought and floods. The data and analyses are disseminated through reports, maps, and computerized information services.

The Office of Management and Budget has designated USGS as the lead agency to run the Water Information Coordination Program. The program is to identify opportunities to make the best use of federal agency resources for water information. As part of the program, USGS chairs the Interagency Advisory Committee on Water Data to promote communication and collaboration and to ensure cooperation among the agencies. USGS staff said that about 30 federal agencies[3] participate on the Committee either as data providers or as data users. Through a large committee, working groups, conferences, and workshops, the advisory committee covers various water data topics and interests. Specific goals of the program include planning, designing, and operating a cost-effective national network for collecting and analyzing water data; avoiding duplication of efforts; coordinating efforts with related committees, such as the meteorological information coordinating committee; and developing uniform standards, guidelines, and procedures for collecting, analyzing, managing, and disseminating water information.

USGS' water data collection activities run by the Water Resources Division provide the basic water data upon which all of the agency's analyses and condition reports rely. Data collected since 1888 have established the baseline condition of water in the United States and constitute the basis for evaluating, developing, and managing the resource. Funding for data collection is derived either singly or from a combination of three major

[3]An agency is defined as a major organization within the federal government below the department level.

sources: the USGS federal program, the federal-state cooperative program, and reimbursements from other federal agencies.

USGS maintains a nationwide system of surface water gauging stations, groundwater observation wells, and surface and groundwater quality sampling sites. The records on streamflow levels, reservoir and lake levels and storage, groundwater levels and flow, and water quality provide the hydrologic information needed by federal, state, local, and private entities to manage water resources. As of fiscal year 1991, data are collected at over 11,000 surface water gauging stations on streams and rivers, at over 1,600 stations on lakes and reservoirs, and at over 33,000 wells for monitoring groundwater.

USGS runs its data collection program mostly through single-state and sometimes through multistate districts that work with federal, state, local, or other public entities. According to USGS district officials, data are collected through a network of gauges that are funded and/or operated by federal, state, and local cooperators. Data are collected only for programs that have cooperating sponsors because there is no federal money for unsponsored data collection. In fact, officials noted that belt-tightening efforts in the past have eliminated duplicative and unnecessary stations. Because data collection at streamflow gauges has been funded for a specific purpose, the network cannot meet all needs. However, the officials said that, according to one study, each gauge serves an average of 2.6 uses through data sharing.

Because the water data program is cooperative, USGS district and regional officials told us that they have many opportunities to coordinate their work with that of federal, state, and other organizations. In their view, this coordination helps to eliminate duplication and improves the usefulness of the data collected.

Through both computer systems and publications, USGS makes available the data collected on levels of surface water, groundwater, reservoirs, or lakes and on water uses. Data are collected on a "real-time" basis by satellite communications at over 3,200 surface water gauging stations. The remainder are collected manually from recorders at the gauging stations every few weeks and loaded into the computer system. All of these data are accessible by computer to other users, such as NWS, the Corps, and the Bureau. The data also appear in many published forms, such as the state-by-state water data reports from USGS detailing annual records for

every station, special USGS studies, or the monthly National Water Conditions report.

National Weather Service

In addition to forecasting the weather and river conditions, NWS monitors drought conditions and issues drought advisories based on its analysis of weather and climate conditions. The analyses and forecasts work are based on data collected directly by NWS and on data from other federal and nonfederal sources.

NWS collects temperature and/or precipitation and other weather data through both manual and automated observations at over 11,000 land sites across the country. The agency is the primary supplier of these data for all users. NWS officials explained that to collect these data NWS and cooperating networks and agencies use instruments and observing systems that range from very simple to very sophisticated.

Surface weather conditions are observed and reported at 1,000 federal or contract land stations. NWS staffs about 240 of these stations, and the others are staffed by other federal agencies (such as the Federal Aviation Administration, the Corps, and the Bureau) or by private parties under agreements with NWS. NWS also obtains daily precipitation totals and temperature extremes from over 10,000 cooperative weather stations where lay persons take weather observations for little or no salary. The weather observation stations are organized into various networks to provide climatic, hydrologic, agricultural, and other services. These services use other agencies' data, such as USGS' streamflow measurements. NWS and other agencies, such as the Corps, often fund instruments at USGS gauging stations to take advantage of satellite or telephone transmission of data in important locations. In addition to using data to provide daily weather services, NWS transmits data to the National Oceanic and Atmospheric Administration's (NOAA) National Climatic Data Center in Asheville, North Carolina, which is responsible for collecting, archiving, processing, and disseminating data for research or other purposes.

Two organizations within NWS are important in monitoring and predicting water supply—both floods and drought. These are the River Forecast Centers (RFC) and the Climate Analysis Center of the National Meteorological Center in Camp Springs, Maryland.

Each of the 13 RFCs is responsible for at least one major river system and is staffed with hydrologists responsible for using computer simulation

models to process and analyze the raw data to issue forecasts and to provide guidance on floods, streamflow, and water supplies to NWS' 52 Forecast Offices across the country. In addition to the real-time data, the RFCs use historical data in models that reflect the runoff characteristics of a particular basin to predict streamflow levels. In the West, the RFCs work with SCS, which collects data on the winter mountain snowpack and its water content, to forecast spring and summer streamflow. The RFCs routinely forecast daily streamflow for those interested in river-related activities, such as navigators and water managers, and forecast seasonal water supply for streams whose principal source of streamflow is snow melt.

The Climate Analysis Center provides national climate assessments and predictions of short-term—1 week to 1 season—variations in temperature and precipitation and distributes its findings through a number of publications and a telephone-accessible computer system. The Center also provides many other climate information, monitoring, and prediction services. During the widespread drought of 1988-89 in the Mississippi Basin, the Center produced a series of "Special Climate Summary" and "Drought Advisory" publications on conditions and impacts. It provides weather support to the U.S. Department of Agriculture (USDA) through the Joint Agricultural Weather Facility, which is operated by NOAA and USDA and publishes the Weekly Weather and Crop Bulletin that describes domestic and worldwide weather and crop conditions.

Soil Conservation Service

SCS conducts the cooperative snow survey program in the western states of Alaska, Arizona, Colorado, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington, and Wyoming. These states rely on snow melt as their primary source of water. The state of California runs an independent program that shares data with the federal program.

The data for the snow survey program are collected in two ways: manually at about 1,200 snow courses and automatically from the approximately 600 sites in the snowpack telemetry network. The information collected by the telemetry system and the snow surveyors is translated into local water supply forecasts that SCS state offices issue monthly from January to June in cooperation with NWS. The snow courses are read manually by SCS staff and cooperating agencies: the Corps, the Bureau, the U.S. Forest Service, and the state of California. Major sectors of the western economy, such as agriculture, industry, and recreation, base their plans on these forecasts.

The snowpack data are also used by SCS in conjunction with NWS' RFCs in the West to produce seasonal water supply forecasts in maps and tables that appear in the joint publication entitled Water Supply Outlook for the Western United States, which is published January through June of each year.

According to the staff of the Portland, Oregon, RFC, the water supply forecasts are developed jointly with SCS and are coordinated with the Corps, the Bureau, and other agencies. Forecasts of streamflow are coordinated by the agencies for forecast points that typically coincide with USGS streamflow gauging stations. The forecasts are made with river basin models adjusted for the unique areas involved and may include snowpack, runoff, precipitation received and forecasted, and temperature data. Also included in the Outlook are data from NWS' National Operational Remote Sensing Center in Minneapolis, which uses measurements of gamma radiation to calculate snow depths.

The Portland RFC's staff told us that the streamflow forecasts are more accurate later in the season because there is not much precipitation to change the streamflow after April 1. In addition to the snow melt water supply forecasts from January to June, the RFCs monitor streamflow conditions and make daily forecasts of high or low flows.

SCS staff at the West National Technical Center in Portland, Oregon, said that about 1,400 copies of the Outlook are mailed to recipients, including federal, state, and local government agencies; water users, such as persons associated with irrigated agriculture, municipal water systems, industry, fisheries, and recreation; elected officials; and reservoir operators, such as the Corps, the Bureau, the Bureau of Indian Affairs, and private power companies.

Other Agencies

In addition to the primary federal data collection agencies, some other federal and state agencies collect their own data or analyze shared data from other agencies for their own drought and water management purposes.

Bureau of Reclamation

After the 1988 drought throughout much of the West and Midwest, the Bureau developed a monthly publication with a year-end summary of water supply conditions for the western United States. The report consists of a narrative and graphic overview for the 17 western states, including data on reservoir levels, streamflow forecasts, accumulated reservoir

inflow, snow water equivalents, accumulated precipitation, and the Palmer Drought Severity Index, which is an NWS tool for measuring relative dryness or wetness that identifies prolonged and abnormal deficiencies or excesses of soil moisture.

Officials of the Bureau's Surface Water Branch in the Denver central office told us that the monthly report was based on data and narrative reports from the Bureau's regional offices on reservoir storage, their streamflow forecasts, and accumulated inflow, as well as data produced by state and federal data collection agencies. The purpose of the water conditions publication is to pull all the data into one report for the Bureau offices, for their water-using constituents, for other agencies, and for the Congress. The report emphasizes maps and charts to convey many details quickly.

Drought Monitoring on Public Lands

The U.S. Forest Service of USDA, in cooperation with the Bureau of Land Management, the National Park Service, the Bureau of Indian Affairs, the Fish and Wildlife Service, and NWS, use weather data from approximately 2,500 manual and remote automated weather stations on or near public lands to assist in the monitoring and control of wild fires and prescribed burnings and to make other natural resources management decisions. The Forest Service also operates an interactive computer system with other federal, state, and private land management organizations to share and disseminate the data and forecasts on weather and fire conditions. Drought is of major interest to these agencies because of its impact on timber, watershed, and air quality management decisions; wildfire potential; fire management; range conditions; and other resource issues.

State of Colorado

The state of Colorado's Water Availability Task Force draws on federal, state, and local data for compilation into a monthly drought assessment for the governor. Data are received from SCS, USGS, the Bureau, NWS, state agencies, and water users. These data are also analyzed by the Colorado state engineer in the Division of Water Resources, who produces a state surface water supply index and its own publication on water supply conditions. If the data and analyses show that predetermined triggering levels have been reached, then higher-level drought assessment and response task forces are activated.

Commonwealth of Pennsylvania

Under its Department of Environmental Resources, the commonwealth of Pennsylvania has established an interagency drought-monitoring committee that meets monthly during drought periods to review indicators assembled by the Department's staff. These indicators include precipitation deficits, groundwater levels, streamflow, key reservoir levels,

and an index that reflects drought severity, streamflow, and surface storage. Each indicator is compared against critical threshold values that could trigger a drought watch, warning, or emergency—each of which is linked to a specific state response.

The Department obtains precipitation data by county from NWS' RFC in Harrisburg, groundwater levels from 50 observation wells from USGS, streamflow levels from 26 representative gauges from USGS, reservoir levels from the Corps and other reservoir operators, and the drought index from the NWS Climate Analysis Center. Department officials told us that once the state or a portion of it is in drought, emergency water restrictions are usually kept in place until groundwater and reservoir levels return to normal, which is after precipitation and streamflow have recovered.

State of California

As noted earlier, California is the only state to conduct its own snow survey program to measure the water content of snow and the anticipated runoff that will feed its reservoirs and water systems. It shares these data with federal data agencies—SCS and USGS—and the major federal project operator—the Bureau of Reclamation. To monitor the status of its water supply, the state also uses monthly and cumulative precipitation data (as compared to average) and reservoir water storage levels in the state. When storage levels in major reservoirs dropped to 54 percent of normal in February 1991 and the outlook for replenishment from the snowpack was bleak, water deliveries from the state's water project were severely cut. The California governor established a "Drought Action Team" that month to coordinate the state's efforts to mitigate the effects of drought.

U.S. Drought Indicators

A drought eventually affects the entire water cycle. Various federal agencies measure and monitor many aspects of the cycle in accordance with their traditional responsibilities and/or needs in carrying out their water-related missions. Just as the definition of drought varies with the impacts focused on, so do the factors measured and used to indicate drought conditions vary. The key factors are estimates of water use, precipitation (including snowpack), temperature, streamflow, groundwater levels, soil moisture, and reservoir and lake levels. The amount of water used for various purposes is also periodically estimated by state and federal agencies for planning purposes. These factors are used directly or analyzed and combined into models or indexes, such as the Palmer Drought Severity Index, and into NWS' precipitation and streamflow forecasts that are used to regularly monitor or anticipate changing conditions.

Table I.1 lists the types of data collected on water conditions, the primary collectors of the data, the frequency of collection, and the purpose of collecting the data. Table I.2 lists the analyses and publications used for monitoring water resources and potential drought conditions.

Table I.1: Raw Data Collected to Monitor Water Resources and Drought

Type of data	Collector	Frequency of collection	Purpose
Estimates of water use	State cooperators	Collected at various times and published by USGS every 5 years	Enables federal, state, and local agencies to quantify water demands and plan for future needs
Streamflow levels	USGS with federal, state, and local cooperators	Collected on a real-time (instantaneous) and manual basis more than once daily	Indicates quantity of water flowing in surface rivers and streams
Reservoir and lake levels	USGS in cooperation with federal, state, and local agencies	Collected and reported at least daily	Indicates the stage (level) of water as compared to a fixed elevation at the gauge
Groundwater levels	USGS and federal, state, and local cooperators	Collected with continuous recorders or manually on a daily, bimonthly, monthly, or occasional basis	Indicates stresses on aquifers, their ability to yield water, and quantity of water stored
Temperature	NWS and cooperators	Collected on a real-time or manual basis daily or more often	Needed in forecasting streamflow from the snowpack and other weather forecasting uses
Precipitation	NWS and cooperators	Collected on a real-time or manual basis daily or more often	Indicates the source of moisture affecting other drought indicators—streamflow, groundwater, reservoir levels— and for other weather forecasting uses
Snowpack	SCS, NWS, and cooperators	Collected manually or on a real-time basis daily	Indicates the water content of the unmelted snow for use in SCS' and NWS' forecasts of streamflow
Soil moisture	NWS, USDA/SCS, and state agencies	Calculated on the basis of precipitation data	Indicates water available in soil and is a factor used in calculating runoff of snowpack and precipitation

Table I.2: Analyses and Publication of Water Resources and Drought Data

Publication or analysis	Source	Frequency	Data covered; other comments
National Water Conditions	USGS	Monthly	Summarizes national weather and consolidates reports on streamflow levels, reservoir and lake levels, groundwater levels, temperature and precipitation forecasts, and the Palmer Drought Severity Index
National Hydrologic Outlook	NWS	3 to 4 times per year in the spring	Snow cover, streamflow, temperature, precipitation, potential water shortages and floods, regional summaries, reservoir storage, current weather summaries, and long-range temperature and precipitation forecasts
Monthly and Seasonal Weather Outlook	NWS	Monthly	Monthly temperature and precipitation outlooks, recent temperature and precipitation maps for the nation and northern hemisphere
Water Supply Outlook for the Western United States	NWS and SCS	Monthly Jan.-June	Snowpack, reservoir storage, streamflow forecasts, and recent precipitation for western states only
Weekly Climate Bulletin	NWS Climate Analysis Center	Weekly	Temperature and precipitation anomalies and major climatic events
Weekly Weather and Crop Bulletin	NWS and USDA	Weekly	Precipitation, temperature, humidity, weather events, national summary, crop progress, international weather and crops, Palmer Drought Severity and Crop Moisture Index maps for nation
Palmer Drought Severity Index	NWS	Biweekly	Calculated using temperature, precipitation, and soil data to produce an index of meteorological drought used by agriculture, government, business, and academic interests and by others
Crop Moisture Index	USDA/ NWS	Weekly	Calculated using current precipitation and surface soil moisture important to crops; used to monitor short-term agricultural conditions
Water Supply Conditions for the Western United States	Bureau	Monthly and year-end summary	Includes Palmer Drought Severity Index, reservoir inflow and storage, recent and forecasted streamflows, accumulated snowpack, and precipitation for the 17 western states

(continued)

Publication or analysis	Source	Frequency	Data covered; other comments
Estimated Use of Water in the United States	USGS	Every 5 years	Estimates usage of surface water and groundwater by type of use and whether it is consumed or returned to the surface or ground for reuse
Drought Advisories	NWS	Issued during specific droughts	Technical summaries and analyses based on recent weather and climate data provided in narrative, numerical, and graphic form

As these tables show, the raw data collected by various federal agencies cooperating with other federal, state, or local agencies are used and reused in analyses and overviews of water and weather conditions tailored to and published for particular types of users—such as agricultural interests, government agencies at all levels involved with water and other natural resources, water project operators, weather observers, and scientists—or for particular states or regions. Many other analyses or reports are done, tailored to particular users. The Corps' field offices, for example, use data that the Corps generates as well as data that other agencies collect to produce reports called "reservoir regulation bulletins" that keep affected interests informed of changes in water conditions and project operations.

Views of Water Data Users

Generally, users of the data collected by federal agencies are satisfied with the data collected on water resources and drought. NWS and USGS staff said that ways to improve their results would be to increase the number of data collection points or the technology used in the various networks they run. In addition, certain users said that methods of reporting and analyzing data could be improved for their particular interests in drought. An analysis of historic data is being conducted to respond to a need for information about drought.

Corps of Engineers

Corps officials in headquarters, as well as in the Baltimore District, told us that the data networks that they receive or fund through USGS and NWS provide complementary coverage. Because streamflow and reservoir levels are the most important drought indicator to the Corps, the Corps funds real-time USGS gauges upstream and downstream of its reservoir projects. The Corps also measures reservoir levels and funds the USGS gauging stations for rainfall, streamflow, and water quality that it needs to manage reservoir operations in a particular basin. In addition to the 8,000 gauges that it funds in whole or in part, the Corps has access to all of the

data that USGS collects with other cooperators, according to headquarters Hydraulic and Hydrology staff. The Corps relies on the real-time NWS data on rainfall gathered through various networks and delivered via a dedicated computer line to the appropriate RFC.

In the first-year report on its National Study of Water Management During Drought, issued in May 1991, the Corps found that the geographic coverage provided by NWS and USGS data was not adequate for site-specific management of drought. They said that more gauges, along with better predictive methods, would allow water managers to defend necessary conservation measures more effectively. A particular problem, in their view, was the measurement of low flows during periods of drought. In contrast to analyses of flooding frequency, which are based on annual events recorded for up to 100 years, analyses of drought for the same period are based on events that can last for years; therefore, the number of events upon which a drought prediction can be based is much smaller than the number available for a flood prediction. As a result, according to the Corps, a "drought of record" is a less reliable indicator for planning than a "flood of record." The report concluded that better data and better analytical techniques would improve water management during drought.

Bureau of Reclamation

Because most of its projects depend on runoff from snowpack, the Bureau relies primarily on full-season forecasts of runoff and water supply based on snow water content to plan operations, according to headquarters and Denver officials. For projects that depend more on rainfall, they said, the Bureau uses NWS forecasts that are good for only a few days. The Bureau's own internal forecasts of snowpack runoff and those from other agencies, such as SCS, are used to plan operations.

The key factor that the Bureau monitors to trigger a drought response is the ability of the current water supply from snowpack runoff, precipitation, and storage to meet the demand. If demand outstrips supply and reserves are used, a drought is indicated, a Bureau staff member explained. While snowpack and precipitation are monitored, reservoir levels measured primarily by the Bureau are the most important determining factor. Bureau staff said that in the dry West, especially during drought, a single year's runoff from snowpack or rainfall may not affect reservoir levels much.

All factors are monitored and considered because all data must be used to make a decision on drought, a Bureau staff member explained. A single

factor like the Palmer Drought Severity Index can indicate drought in the state of California, for example, while the reservoirs remain full. Conversely, the index can indicate the return of soil moisture while the reservoirs remain low.

The officials also said that they were satisfied with data from other agencies. However, they noted that more accurate data would be very desirable but might not be scientifically possible. They said that, to make water allocations for the growing season, the Bureau was very dependent on the accuracy of snowpack runoff projections made as early as February for a 7-month period. In addition, forecasts of rain, unlike forecasts of snowpack runoff, are good for only a week or less. They said that the Bureau typically makes very conservative projections about a project's water supply, revises them periodically, and in normal years includes a reserve for future drought.

Bureau officials mentioned that the Palmer Index is included in the monthly report of water conditions because it is widely used. However, Bureau officials believed that the Surface Water Supply Index developed in Oregon, Montana, and Colorado would be more helpful. This index combines precipitation, snowpack, streamflow, and reservoir storage level data in a single monthly measure of water availability and uses a positive and negative scale similar to the Palmer Index's. Unlike the Palmer Index, which accounts for soil moisture balance, the surface index is appropriate for areas that rely on surface water for irrigation.

Department of Agriculture

USDA's economics staff, which is concerned with the impacts of drought on agriculture, said that the Department was kept informed about the recent drought in California, receiving reservoir level, precipitation, runoff, and other data directly from Bureau headquarters. The economics staff also monitor the snowpack data and forecasts produced by SCS and NWS. They pointed out that the Weekly Weather and Crop Bulletin from the joint USDA/NWS operation packages information specially for agricultural interests. The staff said that NWS' forecasts are used to some extent to anticipate impacts of drought but are of questionable reliability and limited usefulness beyond 10 days.

National Marine Fisheries Service

A National Marine Fisheries Service official involved with the response to the California drought said that at headquarters they depend on the Bureau to provide data on the California water supply, both current and

forecast. They are concerned with the availability of water in rivers and streams for endangered species of salmon that migrate between upstream areas and the ocean. Before the interagency task force on California convened, Fisheries did not receive water data regularly at the headquarters levels. This changed while the task force was meeting. Fisheries regional offices and Bureau regions were reported to communicate more regularly. Fisheries does no water data collection or analysis of its own.

State of Colorado

The federally produced Palmer Index was not specific enough to be useful in the climatically varied state of Colorado, according to a state drought response official. Instead, Colorado uses an enhanced version of the Palmer Index, produced in-state, which subdivides the diverse regions of the state into 25 areas rather than the 5 used by NWS. The Palmer Index is supplemented by the state's own Surface Water Supply Index, which state officials said emphasizes surface water availability more than soil moisture to more accurately indicate the water conditions in Colorado.

Commonwealth of Pennsylvania

Pennsylvania's drought-monitoring official said the state's weak area is collection of data on groundwater levels. At present, the state uses a network of 50 groundwater observation wells run by USGS, and only one-third of them have "real-time" data collection by satellite to collect current data quickly. In addition, the number of long-term records for groundwater wells is limited because some have been abandoned because of outside interference with natural conditions (such as the drilling of new wells), the state official said. Another factor limiting both satellite data collection and the number of wells monitored is funding. The state or another cooperator must pick up 50 percent of USGS' cost.

The staff of the Susquehanna River Basin Commission, which has water management responsibilities in the three basin states of Pennsylvania, Maryland, and New York, told us that USGS tailors the data produced to users' needs and that real-time data are available promptly. They said that NWS' RFC provided very good data on current streamflow conditions and forecasts. Although both USGS and NWS provide streamflow information, the staff said that the NWS center does not collect or maintain historical data, as USGS does.

Study of 1987-89 Drought Finds Room for Improvement

A study of the impacts of and the response to the 1987-89 drought in the Mississippi River Basin and other areas in western and southern United States concluded that the flow of information to government and private decisionmakers was slow and that the information was too ill-defined or poorly analyzed to allow action early in a drought. The authors recommended the creation of a well-coordinated "drought watch" program that would permanently link federal, state, and local resource agencies and serve as a clearinghouse for data and information that required translation and dissemination to decisionmakers.[4]

Views From USGS and NWS on Data Limitations and Improvement

In general, USGS officials said that the data produced were of good quality, but they pointed out limitations in the number of data collection stations and in their agency's control over the quality of the data provided to them by nonfederal cooperators.

Data collected by cooperators, such as state engineers, are subject to quality control by USGS. Officials at USGS' Central Regional Office in Denver said that the data collected by cooperators were reviewed for quality and sometimes not accepted. They said, however, that data were being rejected less and less frequently after quality reviews. They attributed this improvement to USGS' training of and communication with cooperating staff.

Generally, the USGS Central Region and Pennsylvania District officials we interviewed said that the main limitation on the accuracy of analysis based on surface water data is the number of gauging stations, which in turn is constrained by the federal government's and cooperators' budgets. A USGS headquarters hydrologist said that maps showing streamflow conditions are difficult to prepare accurately when gauging stations are sparsely scattered across a wide area, as they are in the western United States. Furthermore, data limitations constrain USGS' ability to project events throughout a basin accurately and specifically. Extreme events such as floods and drought often identify deficiencies in data collection networks when forecasts of these critical events are not accurate. Some quantitative measure of the runoff characteristics (geology) of the basins would also help USGS more accurately predict streamflows with a given amount of snowpack runoff or precipitation.

[4]William E. Riebsame, Stanley A. Changnon, Jr., and Thomas R. Karl, Drought and Natural Resources Management in the United States: Impacts and Implications of the 1987-89 Drought, (Boulder, CO: Westview Press, Inc., 1991).

USGS and states sponsor surveys of water users to determine how water is used in each cooperating state. According to USGS regional and headquarters officials, the results of these surveys may be inaccurate because USGS and the states rely on unverified answers from water users. The water use data are deficient in various ways, depending on the type of water user and the location. For example, in some states where agricultural users are not required to monitor their water use, information about their consumption is not as likely to be accurate. In the West, few water meters are used to measure actual use.

NWS officials acknowledged that the reliability of long-term forecasts of temperature or precipitation ranges and of streamflow is limited and that improvements in the length of reliable forecasts depend on advances in both data and technology. According to a 1991 NWS paper, improved weather, water supply, flood, and drought predictions will be based on an improved understanding of the atmosphere, which will come about through major technological improvements in satellites, weather-surveillance radar, information-processing and communications systems, automated remote sensors, and super-speed computers. All of these improvements are under way, NWS reported.[5]

NWS officials noted that they rely on other agencies to provide streamflow data, while they collect precipitation and temperature data. They noted that the data delivered under time constraints for use in current reports and forecasts on a real-time basis are not subject to the same quality controls as the data archived for historical records. They said that the next generation of weather radar is expected to revolutionize the collection of data on precipitation because the radar will be able to measure overall precipitation in areas where there are no gauges. With the existing point-by-point coverage of precipitation, the amount of rain falling over a region can only be roughly estimated. Determining the exact amount of rainfall is a key factor in deciding whether there is or is not a drought, they said.

NWS analyzes and translates raw data collected on water and weather conditions into publications on current conditions and forecasts. NWS staff said that the final published maps are hand drawn by meteorologists to reflect their best professional judgment of the data and past experience. Headquarters Office of Hydrology staff said that the maps contained in the National Hydrologic Outlook report, for example, are plotted by hand and

[5]Eugene Stallings, "Flood Forecasting and Drought Prediction by the National Weather Service," National Water Summary 1988-89—Hydrologic Events and Floods and Droughts (Reston, Virginia: U.S. Geological Survey, 1991), p. 121.

adjusted for accuracy on the basis of professional judgment. Daily weather maps and the Weekly Climate Bulletin, which give short-term forecasts and previous conditions, are prepared in much the same way, according to NWS' Climate Analysis Center staff. Center staff said that, to make 6- to 10-day, monthly, or seasonal predictions, all available data are fed into models, which produce probable scenarios that are then adjusted and interpreted by the meteorologists. Computer-generated data and maps are combined with hand-drawn maps to give the best possible forecast or representation of recent conditions, they said.

Data used to make the final maps include other agency maps, raw numerical measurements of such factors as snowpack, streamflow, precipitation, reservoir levels, soil moisture, narrative comments of NWS field staff, and verbal comments of headquarters and field staffs on draft maps. Users of these maps should be aware, NWS staff said, that local conditions could vary from those shown. In addition, some of the maps characterize the conditions very generally—average, above average, and below average, for example—without providing any associated numerical ranges. Climate Analysis Center staff said that the sparseness of reporting stations in the West reduces the specificity of forecasts and condition reports. Forecasts are reviewed later to see what improvements the forecasters made over a control forecast generated with random numbers. The results show that, generally, the longer the period forecast, the lower the accuracy of the prediction.

Corps Study to Chart Drought Frequency Probabilities

As part of a national study by the Corps of Engineers to develop a strategy for improving water management during drought, a National Drought Atlas is being prepared jointly by the Corps, USGS, and NOAA National Climatic Data Center. The atlas will provide regional drought planners with accurate, consistent historic records of precipitation, streamflow, the Palmer Drought Severity Index, and reservoir contents. These data indicating drought will be used to present the probability of drought lasting from 1 month to 5 years.

The Corps study manager said the atlas will give a rational basis for managing water during drought. All of the data for the atlas are from USGS or National Climatic Data Center files and have been organized and checked before statistical analyses. Project staff noted that although there is considerable dissatisfaction with the Palmer Index as a drought indicator, it has been included because it is widely used by the states as a basis for planning a response to drought and declaring drought

emergencies. The Corps study manager said that the index is problematic because it yields an approximation of drought that is not well connected to drought impacts, except for agriculture. In contrast, groundwater levels are an important indicator of drought, but they are not included because sufficient data are not available.

The Corps study manager noted that records on fewer events are available for calculating the probability of drought than the probability of flooding because drought occurs over longer periods and is much less frequent; therefore, the results on drought may be less reliable than the results on flooding. USGS staff analyzing streamflow data told us that the records used to calculate drought probabilities were obtained from 1,666 gauging stations that were chosen for their long, stable records at locations where the flow was unregulated. They would have liked to have had more data from unregulated streams in the West and Southwest to fill in geographic gaps. The atlas is scheduled to be published in book and compact disk form in August 1993.

Federal Global Climate Change Activities

Natural variations in climate affect water supply by increasing the frequency of drought or floods. One of the federal government's ongoing challenges is to determine whether these natural variations are exaggerated by global climate change, or the "greenhouse" effect, which involves the increase in levels of carbon dioxide and other gases in the earth's atmosphere.

The presence in the earth's atmosphere of greenhouse gases—carbon dioxide, methane, chlorofluorocarbons (CFCs), and nitrous oxide—has increased at an unprecedented rate. Since the beginning of the industrial revolution, the level of carbon dioxide has increased by 25 percent, which is nearly its total natural increase over the past million years. Even though climate is constantly changing, climate change models show that the continued production of greenhouse gases at current rates may raise average global temperatures by 3 to 9 degrees Fahrenheit during the next century. Such warming could cause shifts in rainfall patterns, have far-reaching effects on water supply and control, and cause severe drought.

However, according to a 1992 Congressional Research Service report, many scientists are uncertain that the link between global warming and human pollution has been firmly established. In a recent report, we observed that available data and scientific limitations leave much

uncertainty surrounding the timing and magnitude of changes in temperature and water resources that can be ascribed to the greenhouse effect.[6]

The federal government participates in a wide range of research activities related to global climate change. Although the executive branch has no single federal agency in charge of monitoring global climate change and its implications, federal efforts to study the impact of global climate change on water supplies are under way. Federal efforts are coordinated through the interagency Global Change Research Program, which comprises 11 agencies that sponsor research designed to reduce scientific uncertainties and develop more reliable predictions about global change. The results are to serve as a basis for a policy response. In fiscal year 1992, the program's funding totaled $1.1 billion within the participating agencies' budgets.

One program under the umbrella of the U.S. Global Change Research Program is the Bureau of Reclamation's Global Climate Change Response Program, a multiyear research program created in 1989 to study the potential impacts of global climate change on water resources in the 17 western states. Participants include EPA and USGS, as well as universities and other organizations. The program consists of three broad categories of projects, which will identify the river basins and water supplies most likely to be at risk from global climate change and will develop scenarios identifying impacts on water demands and resources.

Global climate change scenarios are developed using general circulation models, which are complex computer simulations of the physical forces that produce weather patterns. The models are the most sophisticated tool used to project climatic changes that would result from projected increases in greenhouse gases. However, models and supporting data cannot yet predict the magnitude and rate of change with any certainty. The models divide the world into regions too large to predict local conditions, providing more information on the greenhouse effect on global climate than on regional climate. One goal of the Bureau's program is to create models for smaller regions.

Because of the limitations of scientific modeling, it is not yet known whether global climate change will increase or decrease the water supply. Traditional water resource planning has assumed a stationary climate. However, with global climate change, the traditional assumption that the

[6]Global Warming: Emission Reduction Possible as Scientific Uncertainties Are Resolved (GAO/RCED-90-58, Sept. 28, 1990), p. 42.

climate of the future will essentially repeat that of the past no longer appears valid. The limitations of climate models are expected to decrease over the next 5 to 10 years if improvements are made in computing capabilities and scientists' understanding of the processes involved. Even though the results of present-day models are preliminary, scientists believe that they are disturbing enough to warrant preparation for the possibility of global warming, according to a report on the results of a workshop held for the Corps' National Study on Water Management During Drought.[7]

A National Academy of Science's Committee on Science, Engineering, and Public Policy completed a large study of global climate change in 1992 that supports this conclusion.[8] The study found that, even given the considerable uncertainties in knowledge about the phenomenon, greenhouse warming poses a potential threat sufficient to merit a prompt response by investing in mitigation measures.

Our 1990 report observed that, while research on global warming should reduce uncertainties about the amount of warming and associated climate changes, easy answers are unlikely to emerge. Our work suggested, however, that certain actions in the meantime, such as reducing CFCs and improving energy efficiency, can be justified and should be implemented because they have benefits in addition to reducing greenhouse gases.

[7]Michael C. Rubino, "Planning for Drought in Light of Climate Change," Drought Management and Planning: Proceedings of the Seminar and Workshop, ed. Donald A. Wilhite, et al (Lincoln, NE: University of Nebraska, 1991), p. 221.

[8]Policy Implications of Greenhouse Warming: Mitigation, Adaptation, and the Science Base (Washington, D.C.: National Academy Press, 1992), p. 68.

Federal Coordination of Drought Planning, Monitoring, and Response

No permanent federal organization is responsible for monitoring drought conditions or planning for and coordinating the federal response to drought. Instead, these activities are carried out by individual agencies, which arrange with one another to cooperate and share data. When drought has been severe or had widespread geographic impact, as in the West, the Midwest, the South, and California within the last 20 years, temporary federal interagency coordinating committees have been set up. However, because periodic drought has had more and more significant consequences for large areas and segments of the economy, some observers believe a permanent interagency mechanism would more effectively anticipate drought and promptly resolve differences between agencies or coordinate the federal response to future drought.

Past Federal Drought Coordination Efforts

Several federal agencies are responsible for a multitude of programs that can respond financially and physically to drought impacts. As explained in appendix I, other agencies have related responsibilities for monitoring water and weather. For a few serious droughts with widespread impacts, temporary federal interagency committees or task forces have been created to monitor drought conditions and coordinate the federal response. During these droughts, the number of states establishing ongoing organizations to monitor, plan, and coordinate drought response has increased significantly. In addition, a now defunct federal interagency body—the Water Resources Council (WRC)—addressed water resources planning but did not directly deal with drought.

Coordination of the 1976-77 Drought Response

Governor Richard F. Kneip and Representative James Abdnor of South Dakota requested federal action in July 1976 to respond to severe drought in that state. Drought also extended to North Dakota, Minnesota, Wisconsin and other Midwestern states, California, the Pacific Northwest, and the Great Basin area. The President formed a special Cabinet-level drought committee in late October 1976, which provided the President with a report that summarized the response to date, described the status of the drought, and listed problem areas. The report did not deal with long-term policy questions or propose further short-term drought responses.

After a change in administrations, the federal drought response continued in 1977 with the appointment of a federal drought coordinator in the White House and the preparation of reports on drought impacts, problems, and the response. A White House Study Group was formed that included

participants from the Corps, the Bureau, USGS, NOAA, USDA, the Environmental Protection Agency, WRC, the Federal Energy Administration, and the Federal Disaster Assistance Administration. The resulting drought appraisal report served as the basis of the administration's request to the Congress for emergency drought relief legislation and funding. Although the Congress approved emergency drought relief bills by early May 1977, most of the drought assistance came through regular program authorities and funding from the Interior, Agriculture, and Commerce Departments, according to our 1979 report.[1]

1988 Drought Committee

The drought of 1988 was one of the worst on record for the central United States, and it affected many other areas in the country. In response to requests from Members of Congress and a recommendation from the Office of Management and Budget, the President established the Interagency Drought Policy Committee to monitor the drought and coordinate the federal response. The committee was co-chaired by the Secretaries of Agriculture and the Interior. Participants also included the Corps; the Departments of Commerce, Energy, State, and Transportation; the Council of Economic Advisers; the Federal Emergency Management Agency; the Office of Management and Budget; the Tennessee Valley Authority; and the White House. The committee's working group, composed of staff representing federal agencies administering drought-related programs, met from June through the fall of 1988 and prepared four interim reports and a final report issued on December 30, 1988.

Working group members told us that the interagency committee provided an excellent vehicle for communication and coordination of the drought response. For example, the Agriculture and Interior Departments, aided by the interagency committee, worked out an agreement on water and land banking. In addition, the committee developed a united position to present to the Congress on the type of drought relief legislation needed and an assessment of the drought's conditions and impacts. A working group member also said that the committee coordinated programs to reduce duplication and made adjustments to the drought response under existing programs.

[1]Federal Response to the 1976-77 Drought: What Should Be Done Next? (GAO/CED-79-26, Jan. 31, 1979).

Water Resources Council

WRC was established by the Water Resources Planning Act of 1965 (P.L. 89-90) to promote interagency planning and coordinate policy for water and related land resources programs. It was a sub-Cabinet committee composed of department-level Secretaries, associate members, and observers from other agencies, with a permanent professional staff. The Secretary of the Interior was designated to chair WRC. Under the 1965 act, six river basin commissions were created to prepare regional plans for managing water and related land resources. The act also authorized federal financial assistance to states for developing comprehensive plans for managing water and related land resources. Although WRC did not have formal activities for managing drought, the planning that it promoted and the coordination that it facilitated—especially the informal coordination at the staff level—aided the response to drought, according to former staff members with whom we talked. They said that much of WRC's water management planning was related to drought. However, specific proposals to start planning for drought were usually supported during drought but rapidly lost priority when rains came.

According to a 1981 study, a general criticism of WRC's ability to coordinate and shape policy was that results had to be achieved through voluntary action by the participating federal agencies.[2] The new administration proposed in 1981 to eliminate WRC because, in its view, its programs were not cost-effective and because the President wanted to be more directly involved in water policy issues through the existing Cabinet Council on Natural Resources. The bulk of the funding for WRC and the river basin commissions it started was cut off as of October 1, 1982, and the Council's responsibilities were assigned to Department of Interior agencies. Shortly before WRC became inactive, the staff had written internal proposals calling for more formal planning and coordinating of the federal response to drought. The 1965 act establishing WRC has not been repealed.

Current Federal Drought Coordination Efforts

Recent federal efforts to plan for and coordinate the response to drought continue to consist of individual agencies' activities and an ad hoc coordination effort. The California Drought Task Force, active during our review, provided communication and coordination benefits for the agencies responding to the drought and is the most recent example of the federal government's approach. In addition, contingency planning for drought has been or will be done by the Corps and the Bureau for each

[2]Warren Viessman, Jr., The United States Water Resources Council—Options for Reform (Washington, D.C.: Congressional Research Service, Apr. 1981).

project—in some cases for entire basins. This planning will help to coordinate the future drought response with affected interests.

California Drought Task Force

The Federal Interagency Task Force on the California Drought was established in January 1991 by the Secretary of the Interior at the request of the White House staff as California entered its fifth year of drought. According to Department of the Interior participants, the primary purpose of the task force was to enhance communication among the agencies and to produce a listing of assistance available from federal agencies. No written mission or mandate for the committee was published. Participating agencies besides Interior were the Departments of Agriculture, Commerce, Justice, and the Treasury; the Corps; the Federal Emergency Management Agency; the Council of Economic Advisers; and the Office of Management and Budget.

Task force meetings were held every 2 or 4 weeks during the critical early 1991 winter and spring period when most of California's precipitation is received and allocated; they were held infrequently during the rest of the year. The task force did not meet after the winter of 1992 because water allocations had been set and the situation had not changed. The task force, chaired by Interior's Assistant Secretary for Water and Science, consisted of seven subcommittees whose chairs and vice chairs represented most of the participating agencies at meetings of the task force as a whole.

The participation on the task force of a senior Fish and Wildlife Service headquarters official designated as the Secretary of Interior's representative to the state of California Governor's Drought Action Team provided a direct link with the state. Also participating from Interior were staff from the Bureaus of Reclamation, Indian Affairs, and Land Management; USGS; the National Park Service; the Office of Congressional and Legislative Affairs; the Office of Public Affairs; and the Office of the Solicitor.

Each subcommittee and/or agency represented at the task force meetings provided data on its projects, programs, and water conditions, and each highlighted issues affecting its response to the California drought. For example, implementation of the Endangered Species Act to protect the habitat of migrating salmon affected the allocation of the scarce water between uses in streams or rivers (i.e., fish) and off-stream uses (i.e., irrigation) served by the state and federal water projects. Discussion at the meetings also covered reservoir levels and inflow (water flowing into a

reservoir) for both state and federal water projects and comparisons of the Bureau's measurements of water availability with normal supplies. The task force also heard reports on the content and status of legislative proposals for drought relief.

In general, participants from the various agencies represented on the California task force told us that the primary benefit from the group was better communications, both formal and informal, on drought conditions and the federal response. They said that the organization of the task force as subcommittees provided a ready list of contacts at the staff level within the relevant federal agencies for obtaining information and cooperation.

Although there have been no recent meetings, Interior Department officials said that, as of September 1992, information was still being disseminated among the agencies and informal coordination was occurring through the contacts made on the task force. Interior staff also said the Department's productivity increased because awareness of drought issues and problems had increased and the fact that the Bureau was involving other Interior offices, such as the Fish and Wildlife Service, earlier in managing the drought. In their view, the Bureau's drought management had become more creative and solution-oriented.

The Agriculture Department participant in the task force also viewed gathering and sharing information as the main benefit. This official said that because the impact of drought on California's agriculture depends on water available from the Bureau's irrigation projects, the Bureau was the key source of information. The task force provided a direct connection for Agriculture to the Bureau and to the two federal agencies having the greatest effect on the use of water in California: the Fish and Wildlife Service and the National Marine Fisheries Service. Agriculture contributed information to the task force on the implications of drought and water allocation decisions for agriculture in California and the related federal programs. The Agriculture official noted that the task force had also provided a forum for discussing drought-related legislative proposals.

National Marine Fisheries Service staff, whose interest in the drought was in enforcing the Endangered Species Act for migrating salmon, also said that information and contacts were the most important benefits of participation in the task force. Especially noted were the contacts and interaction with top staff in the Bureau and in Interior headquarters rather than with field staff. Access to the headquarters level allowed Fisheries staff to elevate their agency's concerns about the impact of Bureau

operations on listed species and on critical habitat. Fisheries staff said that the exchange of views on drought with other agencies in the task force widened their perspective on the impact of their programs on the activities of other agencies and on the conflicts among the various agencies' missions.

Officials in the Federal Emergency Management Agency's State and Local Programs Support Directorate said that the task force on the California drought provided their agency with a means to monitor both the California situation and the response to it, although the agency itself was not called upon to respond. They said the task force provided contacts in each agency involved in the California drought response, up-to-date data on the drought, and reports on congressional proposals to respond to the drought. They noted that other agencies, such as the Corps and Agriculture, have the primary responsibility to respond in drought emergencies and that their agency would be the last to respond after local, state, and other federal agency responses were in place. They noted that the task force enabled the federal agencies to respond to local and state officials with a coordinated voice.

Federal Drought Contingency Planning

While the Corps and the Bureau may consider the impact of drought on project operations during their initial development of new water projects, specific contingency planning for drought is a relatively new exercise for the Corps and recently was permanently authorized for the Bureau.

To enable the Corps to respond fully to public needs during a drought, a regulation requiring the Corps to develop drought plans for its controlled reservoir storage projects was established in 1980. By September 30, 1992, the Corps had completed the drought contingency plans for the 334 projects requiring them. Corps Hydraulics and Hydrology Branch staff said the objective of the plans is to improve the Corps' management of the reservoir projects that are affected during drought. As we reported in our 1989 study of the drought in the Savannah River Basin, the plans for all such projects were to include (1) an operating strategy to use a project's existing storage to respond to short-term water shortages; (2) procedures for coordinating decisions with public, state, and local officials; and (3) a mechanism to identify conservation actions needed before a drought crisis.[3]

[3]Water Resources: Corps of Engineers' Drought Management of Savannah River Projects (GAO/RCED-89-169, June 12, 1989).

The Bureau of Reclamation recently obtained permanent authority to develop drought contingency plans. The Reclamation States Emergency Drought Relief Act (P.L. 102-250, Mar. 5, 1992) authorized the Secretary of the Interior to conduct drought contingency planning in consultation with appropriate federal and state officials; Indian tribes; and public, private, and local entities. These cooperative drought contingency plans are to mitigate the adverse effects of drought conditions. The law grants the Secretary this authority permanently, allowing the plans to be developed in advance of drought with the participation of states and other interests. Bureau staff said additional authority is needed from the Congress to include some drought relief actions in contingency plans that go beyond existing reclamation project service areas and authorized project functions. As of February 1993, planning work under the new authorization had not started because the Bureau lacked appropriations for it.

According to a report to the President and the Congress in February 1991 by Interior's Assistant Secretary for Water and Science, contingency planning is valuable because it gives all parties an opportunity to agree in advance about the use of scarce water and resolve procedural and legal problems that could delay implementation of the plans.

In addition to its preparation of drought contingency plans, the Corps' National Study of Water Management During Drought has commissioned "drought preparedness studies" in selected basins to develop drought plans that improve on past management practices, using computer modeling of basins and voluntary committees of water managers, users, advocacy groups, and regional and national experts to balance objectives.

Views on Drought Coordination

Federal water responsibilities are assigned to about two dozen agencies, according to one count. Thus, federal interagency coordination is a significant consideration in planning for drought. The federal and nonfederal staff with whom we talked generally said that interagency coordination at the federal level is beneficial when agencies dealt with drought and other water resource policy issues. Generally, the federal agencies noted that they did coordinate their activities or projects as needed with federal, state, local, or other parties. Recent legislation mandates a comprehensive review of federal water resources activities in the West, including the apparent need for interagency coordination.

Federal Views

An NWS Office of Hydrology official said that WRC had afforded an opportunity to discuss and resolve water policy issues. He believed the recent California drought task force also provided this type of forum. The Interagency Advisory Committee on Water Data operated by USGS has tried to fill part of the void left by WRC's dissolution, but the committee's mandate focuses on the collection of water information only.

Department of Agriculture participants in the 1988 and 1991 drought committees felt that the use of ad hoc groups to coordinate policy during drought was an adequate response and saw no need for establishing a permanent committee. One Office of Economics participant in the 1988 committee noted that each federal agency was set up to adequately address the impacts of drought within its area of expertise. He felt that flexibility should be retained in drought response because each drought was different. For example, the impacts of the current drought were concentrated in the state of California, while in 1988 they were spread across the Midwest. Similarly, the Agriculture Department representative on the California drought task force favored an ad hoc approach, noting that because each drought involved different geographic areas, a permanent committee might be inappropriate and an ad hoc approach better.

As part of a study of water management during drought being conducted by the Corps' Policy and Planning Division and the Corps' Institute for Water Resources, three major workshops were held in 1990 involving the Corps and other federal, state, regional, and university representatives. Participants at each workshop generally agreed that the country would benefit from better interagency and intraagency coordination, according to the Corps' first-year report on the study. Corps representatives felt that there was insufficient agreement among the federal and nonfederal agencies about their respective roles during drought. In addition, Corps representatives identified problems with communication, a lack of common objectives and of a forum for discussion, and a large number of government units needing coordination.

The study recommended interagency coordination to regions that wished to reduce their vulnerability to drought, citing the state of California's successful working relationship among federal, state, and regional water agencies and the Washington, D.C., metropolitan area's cooperative operation of existing storage capacity. The Corps study noted the disappearance at the national level of many interagency coordination and

planning bodies but indicated that the need for these mechanisms was as strong as it had ever been, especially during drought.

Corps headquarters planning and engineering officials said that although they had found the voluntary interagency coordination promoted by WRC and drought committees helpful, they would oppose a coordination body that could require the Corps to modify project operations. They explained that such orders could contradict the project purposes specified in authorizing statutes and could result in illegal operations.

The Deputy Assistant Secretary at Interior, in the office responsible for the task force on the California drought, said he felt there should be a formal, ongoing federal structure to coordinate the federal drought response rather than a temporary body. He said the work of an ongoing group on drought would be useful to the federal agencies and the public when a drought occurs.

Nonfederal Views

The coordinator of the state of Colorado's drought monitoring and response activity said that he and other state officials missed an organization at the federal level to provide a coherent structure and a national forum on water issues and priorities. They complained that there was no federal focal point with a long-term perspective on drought. Rather, he said, the federal government responded agency-by-agency and only after a drought had arrived. The state had to deal with a multitude of federal agencies in responding to drought.

Susquehanna River Basin Commission officials observed that emergency federal drought programs could begin only after local efforts had been exhausted. Neither the Corps nor the Federal Emergency Management Agency is authorized to respond until after the states have acted. In states with a well-prepared drought response system, the federal response is very seldom triggered, commission officials said, except for Agriculture's farm programs.

A 1989 paper by the Western Governors' Association on the broader topic of coordinating federal water policy found that poor federal coordination, both internal and with state policy, was contributing to "gridlock" on water decisions at the state and local levels. The paper found that federal water policies were made in an ad hoc, decentralized manner and lacked a unifying vision or set of guiding principles, helping to cause redundance of functions, protracted disputes, turf battles, and a lack of final policies.

These problems do not help when water supplies are threatened by drought and the demand for water continues to grow, the paper continued. It recommended that the President appoint a White House-headed group, comprising all heads of water-related agencies and a permanent staff, to serve as a forum to improve federal coordination internally and with states.

Association staff said the task force on the California drought was needed to coordinate the federal agencies' response in the state. The staff said that it provided a good forum for communications among the federal agencies. Although the 1989 paper recommended a coordination function for federal water policy, association staff said that drought-specific coordination groups should be temporary.

In a 1991 study of the impacts of the 1987-89 drought in the United States, the authors concluded that beyond specific operational plans, such as the Corps' low-flow management of reservoirs, federal agencies lacked guidelines or legislative authority for dealing with drought, relying instead on an ad hoc response. They said that the nation's lack of general drought contingency planning at the federal level should be corrected. The study found that some drought losses could have been averted by a more organized national system for monitoring and disseminating information. Responsibilities for managing and monitoring water resources were found to be divided, resulting in the neglect or poor management of issues, such as water policy and climate impacts that cut across institutional lines. They recommended creating a well-coordinated "drought watch" program that would continuously link federal, state, and local resource agencies and provide a clearinghouse for data and information that needed to be analyzed and disseminated to decisionmakers.

Water Policy Review Is Mandated

The Western Water Policy Review Act of 1992 (title XXX, P.L. 102-575, Oct. 30, 1992) directed the President to establish a Western Water Policy Review Advisory Commission in order to undertake a comprehensive review of federal activities in the 19 western states, including Alaska and Hawaii, that directly or indirectly affect the allocation and use of water resources. Among the congressional findings driving the mandate for the policy review were the following:

- The demands on the finite water supply are increasing.
- Coordination on both the federal and the local level is needed to achieve water policy objectives.

- No fewer than 14 federal agencies are currently charged with overseeing aspects of water policy.
- The diverse authority over federal water policy has resulted in unclear goals and inefficient handling of the nation's water policy.
- The conflict between competing goals and objectives by federal, state, and local agencies, as well as by private users, is particularly acute in the western states.

The Secretaries of the Interior and of the Army were directed to use their resources to assist in the comprehensive review, which is to report to the Congress by October 30, 1995, on its findings and recommendations.

State Drought Planning and Coordination

Until the mid-1970s, when drought caused great impacts and state responses were found to be inadequate, state governments usually were passive in efforts to monitor, plan for, and respond to drought. According to a report funded as part of the Corps' drought study, the drought generated considerable interest among states in contingency planning.[4] The report indicated that, as of 1982 only three states had developed plans, but, as of June 1990, 22 states had developed plans and another plan was in process.

The report found that state drought plans have several common elements:

- A task force is responsible for operating the drought response system, reports directly to the governor, and provides data on water availability, potential problems, and policy options.
- A monitoring system is established to gather data on water availability from state and federal agencies and to provide the information to the drought task force, which issues reports and makes recommendations as appropriate.
- A formal mechanism, such as a committee or working groups, assesses the potential impacts of water shortages on the most important sectors of the economy.
- A committee or the task force itself considers current and potential impacts and recommends options for response to the governor.

The assessment pointed out that state plans are often developed in response to problems during a drought and that the plans' usefulness depends on their implementation during actual drought. In visiting with

[4]Benedykt Dziegielewski, Gary D. Lynne, Donald A. Wilhite, and Daniel P. Sheer, National Study of Water Management During Drought: A Research Assessment, (Fort Belvoir, VA: U.S. Army Corps of Engineers, Institute for Water Resources, Aug. 1991), p. 50.

state officials who were responsible for monitoring and responding to drought in Colorado and Pennsylvania, we found that, in these western and eastern states, plans with the elements listed above had been established and used during drought.

Objectives, Scope, and Methodology

Our objectives were to review (1) the data gathered and used by federal agencies to report drought conditions and (2) the past and current federal mechanisms to plan, monitor, and coordinate a response to drought.

To address these issues, we contacted officials at the following locations:

- Department of the Interior: Office of the Assistant Secretary for Water and Science and Office of the Assistant Secretary for Fish, Wildlife, and Parks, Washington, D.C.;
- Bureau of Reclamation: headquarters and Denver, Colorado, offices;
- U.S. Geological Survey: headquarters Water Resources Division in Reston, Virginia; Colorado District and Central Region offices in Denver; and Pennsylvania District in Lemoyne;
- U.S. Army Corps of Engineers: headquarters in Washington, D.C.; Institute for Water Resources, Fort Belvoir, Virginia; and district in Baltimore, Maryland;
- U.S. Department of Agriculture: Office of the Assistant Secretary for Economics, Washington, D.C.; and the Soil Conservation Service headquarters in Washington, D.C.; and the West National Technical Center, Portland, Oregon;
- U.S. Department of Commerce: National Oceanic and Atmospheric Administration, National Weather Service headquarters in Silver Spring, Maryland; Climate Analysis Center/NWS in Camp Springs, Maryland; Joint Agricultural Weather Facility/NWS at USDA headquarters; River Forecast Centers/NWS, in Harrisburg, Pennsylvania, and Portland, Oregon; and National Marine Fisheries Service in Silver Spring, Maryland;
- Federal Emergency Management Agency: headquarters in Washington, D.C.;
- State of Colorado: Water Conservation Board and Division of Emergency Services, Denver;
- Commonwealth of Pennsylvania: Department of Environmental Resources, Bureau of Water Resources Management in Harrisburg;
- Western Governors' Association: Washington, D.C., office;
- Susquehanna River Basin Commission: headquarters in Harrisburg, Pennsylvania.

We also contacted former staff members of the Water Resources Council in the Washington area. We obtained relevant private and government reports, studies, books, journal articles, correspondence, regulations, water data reports and computer output, public statements, and testimony for review and analysis.

To develop our description of the data gathered and used by federal agencies to report current water resource conditions and to forecast weather and water supply, we interviewed officials in the organizations listed above about the data they collect, analyze, publish, and/or use to monitor and anticipate drought conditions. We reviewed the data and obtained the views of officials from each organization on the development, analysis, and use of the data.

To describe the past and current federal mechanisms for planning, monitoring, and coordinating a response to drought and to explain how these mechanisms worked in recent droughts, we interviewed the officials in these organizations about their experience and knowledge of past and current efforts to monitor, coordinate, and respond to drought. We asked state officials and representatives of nongovernment organizations about their experiences with drought coordination and their views on federal efforts. We also consulted written reports to obtain information on federal research related to global climate change.

We performed our work between March 1991 and December 1992 in accordance with generally accepted government auditing standards.

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