

# **Improving Drought Management in the West**

The Role of Mitigation  
and Preparedness

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***Donald Wilhite, Director  
National Drought Mitigation Center  
University of Nebraska***

**Report to the Western Water  
Policy Review Advisory Commission**

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*June 1997*

## The Western Water Policy Review Advisory Commission

Under the Western Water Policy Review Act of 1992 (P.L. 102-575, Title XXX), Congress directed the President to undertake a comprehensive review of Federal activities in the 19 Western States that directly or indirectly affect the allocation and use of water resources, whether surface or subsurface, and to submit a report of findings to the congressional committees having jurisdiction over Federal Water Programs.

As directed by the statute, the President appointed the Western Water Policy Review Advisory Commission. The Commission was composed of 22 members, 10 appointed by the President, including the Secretary of the Interior and the Secretary of the Army, and 12 members of Congress serving *ex-officio* by virtue of being the chair or ranking minority member of the 6 congressional committees and subcommittees with jurisdiction over the appropriations and programs of water resources agencies. A complete roster is provided below.

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### This is an Independent Report to the Commission

The report published herein was prepared for the Commission as part of its information gathering activity. The views, conclusions, and recommendations are those of the author(s) and are not intended to represent the views of the Commission, the Administration, or Members of Congress serving on the Commission. Publication by the Commission does not imply endorsement of the author's findings or recommendations.

This report is published to share with the public the information and ideas gathered and considered by the Commission in its deliberations. The Commission's views, conclusions, and recommendations will be set forth in the Commission's own report.

*Additional copies of this publication may be obtained from the National Technical Information Service, 5285 Port Royal Road, Springfield, Virginia, 22161; phone 703-487-4650.*

# Contents

	<i>Page</i>
Introduction .....	1
The Concept of Drought .....	2
Crisis Management Versus Risk Management Approach to Drought Management .....	4
The Climatology of Drought in the West: 1895 to 1996 .....	6
The Climatology of Drought, 1986 to 1996 .....	8
State-Level Drought Planning: Current Status .....	17
Lessons From Recent Droughts: State-Level Mitigation Tools .....	21
Integrating Drought Management and Water Policy .....	27
Integrating Drought Management and Water Policy: New Directions ....	39
Australian National Drought Policy: A Model for the United States? .....	41
Conclusions and Recommendations .....	43
Bibliography .....	45

## Tables

	<i>Page</i>
1 Drought-related mitigative actions taken by States during recent droughts .....	23
2 Possible risk-management and risk-minimization measures the Federal Government could consider to lessen the effects of drought .....	36

## Figures

	<i>Page</i>
1 Percent area of the United States (48 contiguous States) in severe and extreme drought (i.e., $\leq -3.0$ ), 1895 to 1995 .....	8
2 Percent area of: (a) Pacific Northwest Basin, (b) Missouri Basin, and (c) Upper Colorado Basin in severe and extreme drought (i.e., $\leq -3.0$ ), 1895 to 1995 .....	9
3 Percent area of: (a) Great Basin, (b) California Basin, and (c) Lower Colorado Basin in severe and extreme drought (i.e., $\leq -3.0$ ), 1895 to 1995 .....	10
4 Percent area of: (a) Arkansas-White-Red Basin, (b) Rio Grande Basin, and (c) Texas Gulf Basin in severe and extreme drought (i.e., $\leq -3.0$ ), 1895 to 1995 .....	11
5 Percent area of Souris-Red-Rainy Basin in severe and extreme drought (i.e., $\leq -3.0$ ), 1895 to 1995 .....	12
6 Percent area of the United States (48 contiguous States) in severe and extreme drought (i.e., $\leq -3.0$ ), 1895 to 1995 .....	12
7 Six-month SPI map for the end of March 1996 (representing the period October 1995 through March 1996) .....	15
8 Palmer Drought Severity Index map, March 30, 1996 .....	16
9 Status of State drought plans, August 1996 .....	18

## Introduction

Water is certainly one of the defining environmental issues in the West today. In a region marked by increasing and shifting population, increasing urbanization, changing trends and patterns of water use, changes in social behavior, and growing environmental awareness and concern, water is and will continue to be a primary source of conflict and controversy. It is imperative that we address these conflicts in a timely and systematic manner as they evolve and before they reach crisis proportions.

Drought, a normal part of the climate for virtually all regions of the United States, is of particular concern in the West, where an interruption of the region's already limited water supplies for extended periods of time can produce devastating impacts. Historical records indicate that drought occurs somewhere in the West almost every year; however, multiyear droughts are of greatest concern to water planners, natural resource managers, and policymakers. The severe multiyear droughts that plagued the region during the 1930s and 1950s are now a distant memory for most. A recurrence of these multiyear droughts today would result in substantially greater and more varied impacts because of the rapid expansion and urbanization of the region's population during the past several decades and the associated increased pressure on water and other natural resources, even though there has been a significant increase in water storage facilities and the application of water-conserving technologies.

The severe drought of 1976 to 1977 in California, the Pacific Northwest, and other portions of the region demonstrated the continuing vulnerability of the region. This vulnerability became even more apparent during the period from 1987 to 1992, when some parts of the West experienced six or seven consecutive years of drought. Drought conditions returned to large portions of the region in 1994 (mainly California, the Pacific Northwest, and the Great Basin States) and again in 1996 (mainly the Southwest and Southern Great Plains States). The 1996 drought caused significant impacts in agriculture and forestry and resulted in depleted reservoirs, increased groundwater pumping, interruptions of public water supplies, and reduced recreational opportunities and tourism revenues. Environmental and social impacts were significant, particularly the tremendous increase in forest and range fires, soil erosion, and effects on fish and wildlife populations.

The Western Water Policy Review Advisory Commission (Commission) has been charged to conduct a "comprehensive review of Federal activities in the 19 Western States which directly or indirectly affect the allocation and use of water resources, both surface and subsurface." Given that drought is a normal feature of the climate in the West, a critical element of this review process must be the future role of the Federal Government in preparing for and mitigating the effects of drought. Future policies and activities must include drought management as an integral part of water management in the

West; this will require an interagency approach that extends well beyond the traditional water mission agencies.

The purpose of this report to the Commission is to provide an overview and analysis of drought and drought management issues in the West and to propose recommendations for improving the coping capacity of the region. The report is divided into five sections. First, the concept of drought will be discussed to provide the reader with a greater awareness and understanding of this complex and insidious natural hazard. Second, the climatology of drought in the Nation and the region will be reviewed, particularly for the period since 1986. This will help place the recent series of dry years in a historical context. Third, the status of State drought planning efforts will be reviewed, particularly in terms of the progress that has been made in the past decade. Fourth, the mitigative actions employed by States in response to recent drought will be analyzed to demonstrate the wide range of options now available to address drought-related problems. Fifth, the results and recommendations of several recent studies will be reviewed and synthesized to determine the necessary next steps toward a more integrated approach (i.e., between levels of government) to drought and water management in the West and the Nation.

## **The Concept of Drought**

Drought differs from other natural hazards in several ways. First, it is a "creeping phenomenon," making its onset and end difficult to determine. The effects of drought accumulate slowly over a considerable period of time and may linger for years after the termination of the event. Second, the absence of a precise and universally accepted definition of drought adds to the confusion about whether or not a drought exists and, if it does, its severity. Third, drought impacts are less obvious and spread over a larger geographical area than are damages that result from other natural hazards. Drought seldom results in structural damage. For these reasons, the quantification of impacts and the provision of disaster relief is a far more difficult task for drought than it is for other natural hazards.

Because drought affects so many economic and social sectors, scores of drought definitions have been developed by a variety of disciplines. In addition, because drought occurs with varying frequency in nearly all regions of the globe, in all types of economic systems, and in developing and developed countries alike, the approaches taken to define it should be impact and region specific. The lack of a precise and objective definition in specific situations

has been an obstacle to understanding drought, which has led to indecision and/or inaction on the part of managers, policymakers, and others. It must be accepted that the importance of drought lies in its impacts.

Drought has been grouped by type as follows: meteorological, agricultural, hydrological, and socioeconomic (Wilhite and Glantz, 1985). Meteorological drought is expressed solely on the basis of the degree of dryness (often in comparison to some "normal" or average amount) and the duration of the dry period. Definitions of meteorological drought must be considered as region specific, since the atmospheric conditions that result in deficiencies of precipitation are highly variable from region to region. Agricultural drought specifically concerns the effects of water shortages on crops and grasses and other forages. Therefore, agricultural drought is most closely associated with deficiencies that occur in soil moisture and lead to losses in yield. Agriculture is usually the first sector to experience the devastating effects of drought. Hydrological droughts are concerned more with the effects of periods of precipitation shortfalls on surface or subsurface water supply (i.e., streamflow, reservoir and lake levels, groundwater) rather than with precipitation shortfalls. Hydrological droughts are usually out of phase with meteorological and agricultural droughts. Water in hydrologic storage systems (e.g., reservoirs, rivers) is often used for multiple and competing purposes, further complicating the sequence and quantification of impacts. Competition for water in these storage systems escalates during drought, and conflicts between water users increase significantly. Because regions are interconnected by hydrologic systems, drought occurring upstream may result in serious impacts downstream as surface and subsurface water supplies are affected, even though downstream areas may not be experiencing meteorological drought. Upstream changes in land use (e.g., deforestation, changes in cropping patterns) may alter runoff and soil infiltration rates, which may affect the frequency and severity of droughts downstream.

Finally, socioeconomic drought associates the supply of and demand for some economic good with elements of meteorological, agricultural, and hydrological drought. Time and space processes of supply and demand are the two basic processes that should be considered for inclusion in an objective definition of drought. For example, the supply of an economic good (e.g., water, forage, hydroelectric power) is weather dependent. In most instances, demand is increasing as a result of increasing population and/or per capita consumption. Therefore, drought could be defined as occurring when the demand exceeds supply as a result of a weather-related supply shortfall. This concept of drought supports the strong symbiosis that exists between drought and

human activities, reemphasizing the importance of managing natural resources in a sustainable manner.

It is critical to note that the economic, social, and environmental impacts of drought are the product of both the natural event (i.e., meteorological drought) and the vulnerability of society to extended periods of precipitation deficiency. Expressed another way, the impacts that result from future drought occurrences will be determined not only by the frequency and intensity of meteorological drought, but also by the number of people at risk and their degree of risk. If demand for water and other shared natural resources is increasing societal vulnerability to water supply interruptions caused by drought, then future droughts can be expected to produce greater impacts, with or without any increase in the frequency and intensity of meteorological drought. If projected changes in climate because of increased concentrations of greenhouse gases occur (Houghton et al., 1990), there will be accompanying changes in regional hydrology, further aggravating the West's already high sensitivity to climate variability. Policies that promote the development and implementation of regionally appropriate drought mitigation measures today will help to reduce the economic, social, and environmental impacts associated with future droughts and the need for government intervention, whether or not future changes in climate alter the frequency and intensity of meteorological drought. The Office of Technology Assessment (OTA), U.S. Congress (1993), refers to measures and policies of this type as "no-regrets" options and recommends that they be adopted to make the Nation more resilient to projected changes in climate.

### **Crisis Management Versus Risk Management Approach to Drought Management**

The traditional mindset of government in the United States and elsewhere has been to react to drought (i.e., crisis management approach) by providing relief or emergency assistance to the affected areas or sectors. By following this approach, drought only receives the attention of decisionmakers when it is at peak levels of intensity and spatial extent and when water management options are quite limited. This approach is sometimes referred to as the "hydro-illogical cycle,"<sup>1</sup> where concern and panic lead to a reactive response to associated economic, social, and environmental impacts, followed by apathy when rains return to normal. This approach has been characterized as

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<sup>1</sup> Hydro-illogical cycle is often used to explain the crisis management approach to drought management. The hydro-illogical cycle is discussed at the National Drought Mitigation Center's (NDMC) home page (<http://enso.unl.edu/ndmc>) and at Wilhite (1993b).



ineffective, poorly coordinated, and untimely (General Accounting Office [GAO], 1979; Wilhite, et al., 1986; Riebsame, et al., 1991; Wilhite, 1993a). Not only is this approach extremely costly, relief provided through this process is often politically driven, programmatically misdirected, and poorly targeted. Relief often serves as a disincentive for the sustainable management of natural resources because it reinforces existing management practices, practices that may not be sustainable in the long term. The provision of relief has been the most common approach taken by Federal Government in the United States to alleviate the impacts of drought. This reactive approach is not good policy and must be replaced by an anticipatory, preventive approach that reduces risk (i.e., risk management) through the adoption of appropriate mitigation programs and policies. James Lee Witt of the Federal Emergency Management Agency (FEMA) recently concluded that the Nation will receive two dollars in savings from future disaster costs from every dollar spent on mitigation (Natural Hazards Observer, 1996). This is likely a very conservative estimate of the benefits received from investments in mitigation.

Technological and social change is improving our Nation's ability to more effectively manage water and other shared natural resources during periods of drought. These changes can facilitate the shift to risk management because they will allow the Nation to address some of the more serious deficiencies of the crisis management approach. For example, our ability to monitor and disseminate critical drought-related information has been enhanced by new technologies such as automated weather stations, satellites, computers, and improved communication techniques (e.g., Internet). Previous drought response efforts have been hampered by a lack of adequate early warning systems and insufficient information flow within and between levels of government. Simultaneously, an improved understanding of complex atmospheric-oceanic systems and the development of new computer models have improved drought forecast skills for some regions. If they become part of a comprehensive early warning system, these advancements and others can provide decisionmakers with better and more timely data and information. The growth in the number of States with drought plans has also helped to provide a more coordinated drought response effort, especially since most of these response plans include a comprehensive monitoring system. This progress will be discussed in greater detail later in this report. It is important to note, however, that the collective experiences of these States in responding to recent years of drought provide a significant record of "lessons learned" in mitigating the effects of drought. The National Drought Mitigation Center (NDMC) at the University of Nebraska-Lincoln has as one of its primary goals the documentation,

evaluation, and dissemination of these experiences to users/clients through its home page on the World Wide Web<sup>2</sup> as well as through its workshops, conferences, and publications. These lessons provide numerous examples of how society can adjust and adapt to the increasing demand and competition for water and other natural resources. Future water policies must be more flexible so that changes in water demand and use and social priorities can be incorporated with relative ease.

## **The Climatology of Drought in the West: 1895 to 1996**

Drought is a normal, recurrent feature of the climate of virtually all portions of the United States. Because of the country's size and the wide range of climatic regimes present, it is rare for drought not to exist somewhere in the country each year. Figure 1 provides a historical perspective of the percent area of the country (48 contiguous States) in severe to extreme drought, according to the Palmer Drought Severity Index (PDSI) (Palmer, 1965) from 1895 to 1995. Severe and extreme drought are represented by values of  $\leq -3.0$  on the PDSI scale. PDSI values commonly range from +4.0 (extreme wetness) to -4.0 (extreme drought), although values above and below these levels are often computed. For example, during August 1977, PDSI values reached -7.0 in parts of the upper Midwest and -9.0 in eastern Oregon and Washington. Until recently, the PDSI was the only index used to monitor or assess climatic conditions on a national basis. The NDMC at the University of Nebraska-Lincoln is currently producing, in collaboration with the Western Regional Climate Center and the National Climatic Data Center, monthly maps of the Standardized Precipitation Index (SPI) (McKee et al., 1993; 1995) at 1-, 3-, 6-, 9-, and 12-month time intervals. These maps are available on the NDMC's home page. They can be used in conjunction with the PDSI maps to assess the status of moisture conditions nationwide.

Figure 1 reveals two features of drought in the United States: (1) its variable but recurrent nature and (2) the magnitude and duration of the droughts of the 1930s and 1950s in comparison to other episodes during the time series. Drought frequently affects more than 10 percent of the Nation, and it is not uncommon for more than 30 percent of the Nation to be affected. The most benign climatic periods occurred around the mid-1940s, between the late 1960s and mid-1970s, and from 1978 to 1985. In contrast, the 1930s drought

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<sup>2</sup> The NDMC has established a home page on the World Wide Web (<http://enso.unl.edu/ndmc>). The home page is designed as an electronic textbook containing information divided into 10 sections: About the NDMC, Drought Watch, Mitigating the Impacts of Drought, Drought Climatology, The Enigma of Drought, Why Plan for Drought?, What's New, Drought Planner's Handbook, Directory of Drought Planners, and Other Places to Go.

continued for nearly a decade; PDSI values of  $\leq -3.0$  (severe and extreme drought) were recorded over approximately 65 percent of the country and more than 95 percent of the Great Plains at the peak of the drought in 1934. The 1950s drought began in the Southwest and Southern Great Plains States in the late 1940s and persisted through 1957. The geographical area affected during the 1950s was quite similar to the area affected by the 1996 drought. At its peaks in 1954 and 1956, severe to extreme drought affected nearly 50 percent of the Nation.

Figure 2 illustrates the percent area in severe and extreme drought for three western river basins (Pacific Northwest, Missouri River, and Upper Colorado) during the period 1895-1995. Each of these time series illustrates the frequency of drought in the region. Particularly revealing is the number of times that drought affected more than 80 percent of each basin. Figure 2 also reveals the intensity and duration of the 1930s drought in the Pacific Northwest and Missouri River basins, the 1950s drought in the Missouri and Upper Colorado basins, the late 1890s and early 1900s drought in the Upper Colorado, and the 1987 to 1995 droughts in all three basins. These drought time series for the other river basins in the West are shown in figures 3-5.

Clearly, no portion of the West is immune to the ravages of drought. An analysis of PDSI values for the period from 1895 to 1995 indicates that drought occurs with much greater frequency in the West than it does in other regions of the country. Most of the West experiences severe to extreme drought more than 10 percent of the time, and a significant portion of the region experiences severe to extreme drought more than 15 percent of the time. For the period from 1985 to 1995, large portions of Washington, Oregon, Wyoming, and Idaho and smaller portions of North Dakota, Nevada, Utah, and California experienced severe to extreme drought more than 30 percent of the time. Drought returned to the Southwest and Southern

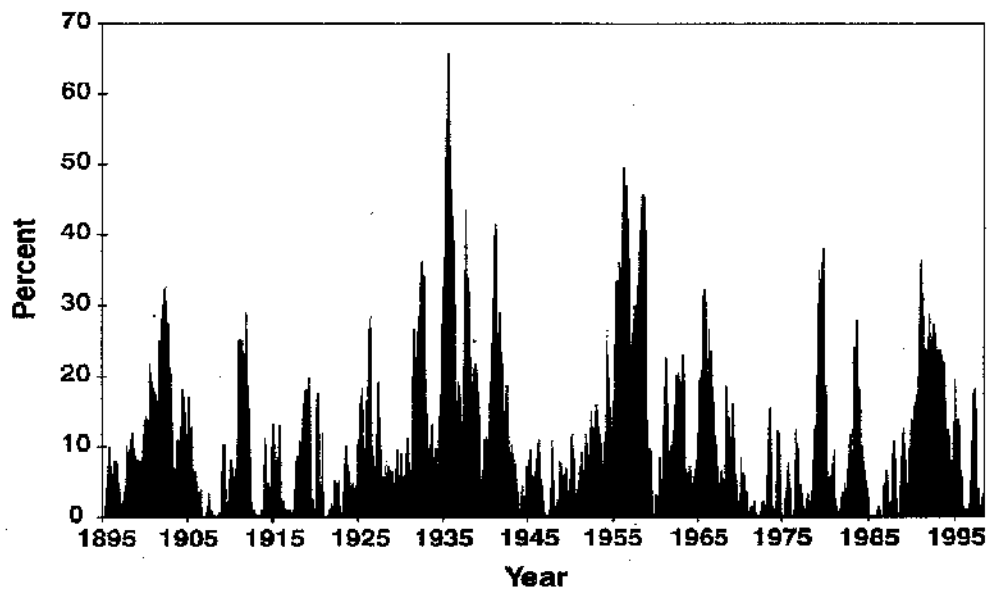


Figure 1.—Percent area of the United States (48 contiguous States) in severe and extreme drought (i.e.,  $\leq -3.0$ ), 1895 to 1995.

Great Plains States again in 1996 when most of this region experienced one of their worst droughts on record. The chronology of drought in the United States during the last decade is described in greater detail below.

### The Climatology of Drought, 1986 to 1996

The most recent series of drought years in the West began in 1986 (see figure 6). Dry conditions in late 1985 persisted through the midsummer months. Drought conditions extended from the South Central States to the Atlantic Coast. The drought's epicenter extended from central Tennessee and Kentucky to central South Carolina and from Virginia to central Georgia; precipitation in the core area was  $< 40$  percent of normal from December 1985 to July 1986. In early August 1986, moderate (PDSI  $\leq -2.0$ ) to extreme drought extended from southern Pennsylvania to central Florida and west to central Louisiana. Moderate to extreme conditions also existed in California and the Pacific Northwest and in parts of the Northern Rocky Mountain States and Central Great Plains States.

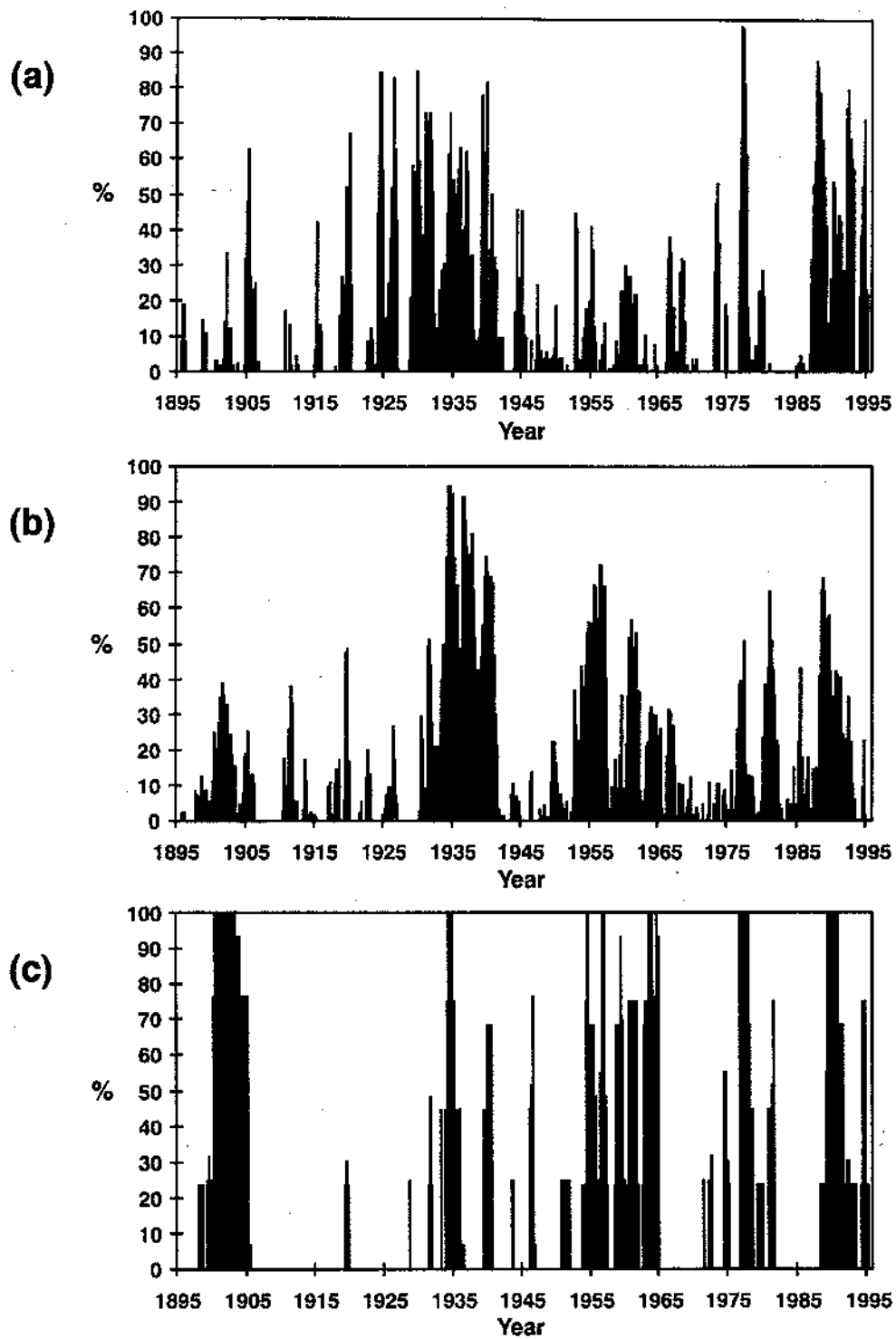


Figure 2.—Percent area of: (a) Pacific Northwest Basin, (b) Missouri Basin, and (c) Upper Colorado Basin in severe and extreme drought (i.e.,  $\leq -3.0$ ), 1895 to 1995.

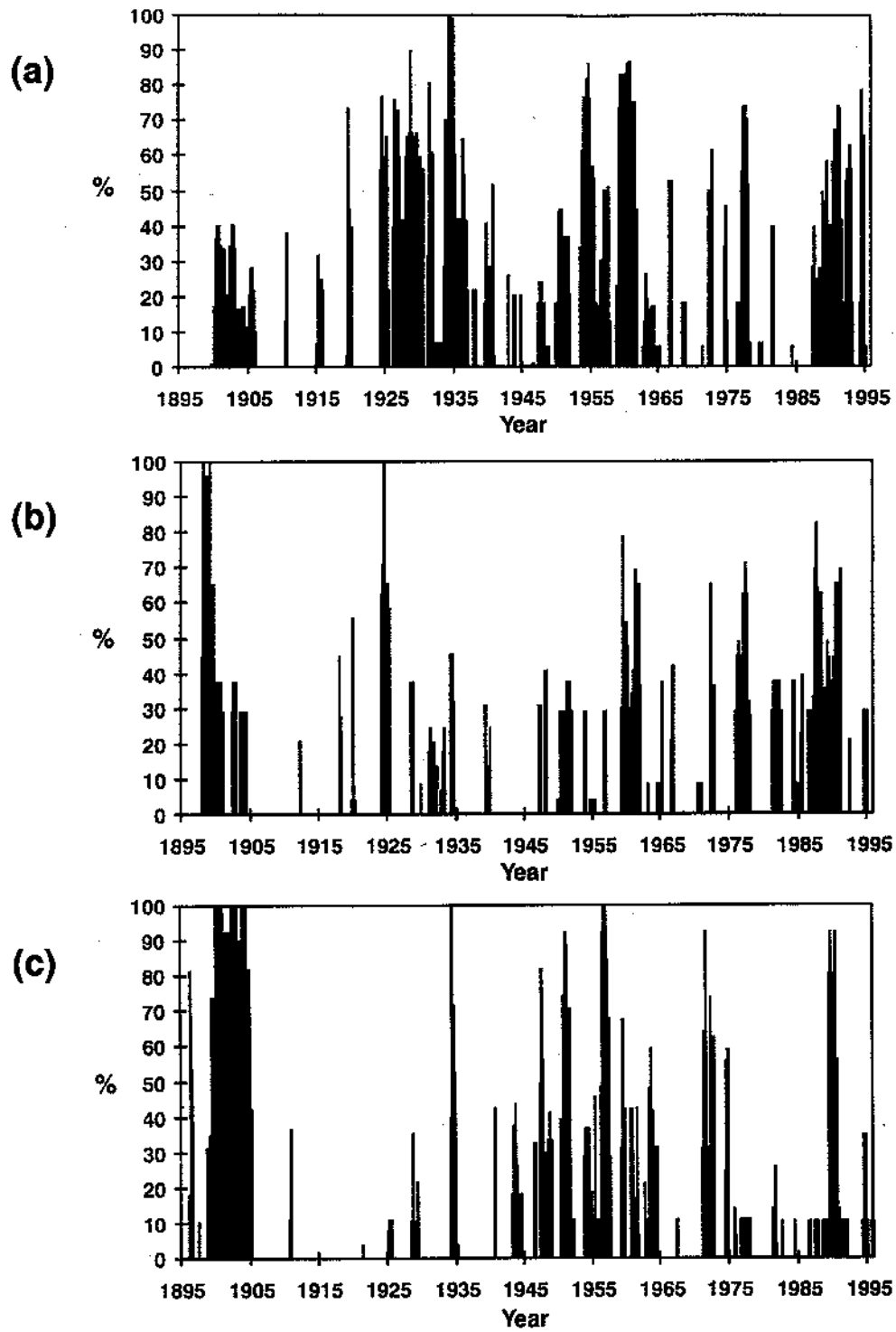


Figure 3.— Percent area of: (a) Great Basin, (b) California Basin, and (c) Lower Colorado Basin in severe and extreme drought (i.e.,  $\leq -3.0$ ), 1895 to 1995.

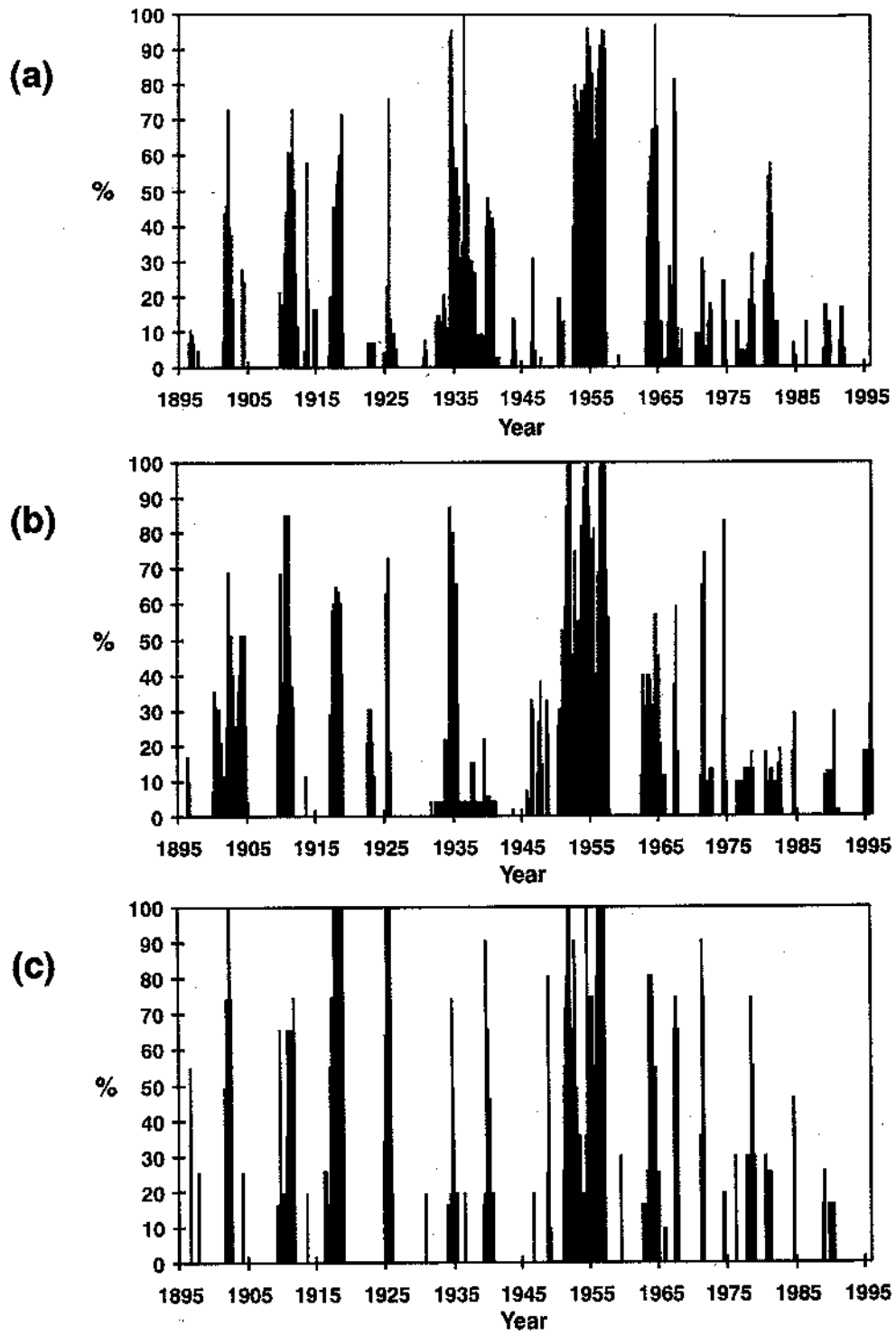


Figure 4.—Percent area of: (a) Arkansas-White-Red Basin, (b) Rio Grande Basin, and (c) Texas Gulf Basin in severe and extreme drought (i.e.,  $\leq -3.0$ ), 1895 to 1995.

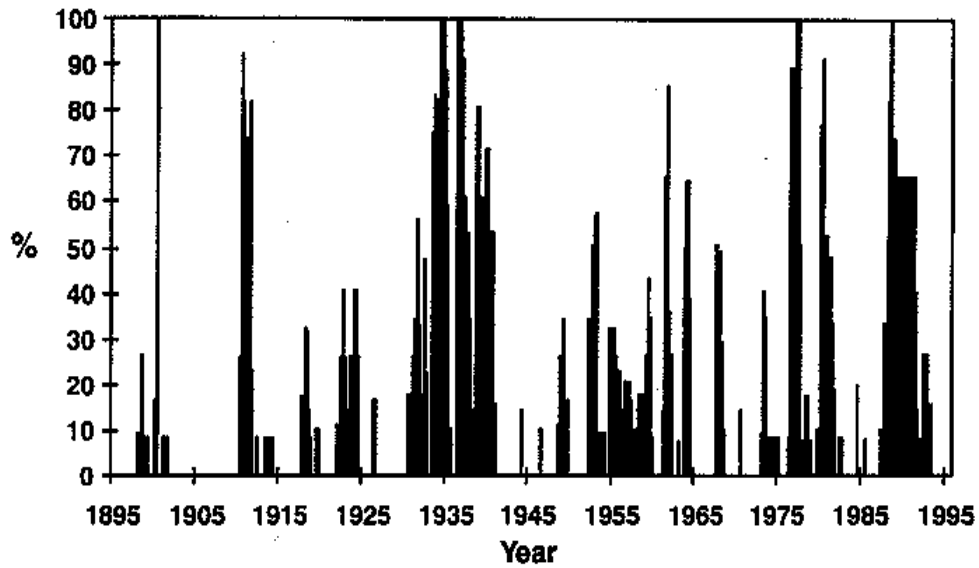


Figure 5.—Percent area of Souris-Red-Rainy Basin in severe and extreme drought (i.e.,  $\leq -3.0$ ), 1895 to 1995.

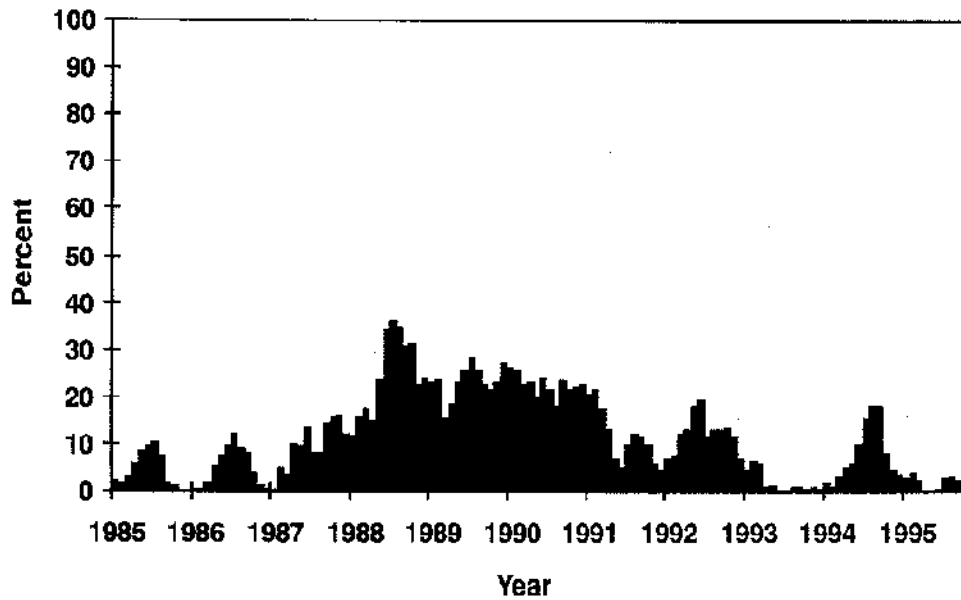


Figure 6.—Percent area of the United States (48 contiguous States) in severe and extreme drought (i.e.,  $\leq -3.0$ ), 1895 to 1995.



Drought conditions abated in early 1987 but reappeared quickly in the spring. Moderate to extreme drought was widespread over the Western United States by August, and moderate drought reappeared in the Southeast and spread west into the Midwestern Corn Belt States. Pockets of severe to extreme drought developed in portions of the Tennessee, Ohio, and Mississippi River

Valleys, a forewarning of events to come. By the end of 1987, approximately 17 percent of the Nation was experiencing severe to extreme drought.

By April 1988, drought conditions in the West had deteriorated significantly. Severe to extreme drought affected all of California, Oregon, Washington, and Idaho; northern portions of Utah; and western portions of Wyoming and Montana. In addition, moderate drought had spread into eastern Wyoming and Montana. Significant pockets of moderate to severe drought had formed in Minnesota, eastern portions of North Dakota and South Dakota, and New England. Moderate to extreme drought persisted in the Southeast. By late May, drought in the West, northern Great Plains, and upper Midwest had intensified and spread into adjacent States. The drought area in the Southeast also began to spread northward into Indiana, Ohio, Illinois, and Iowa. By late July, the intensity had worsened, and the spatial coverage had increased. The drought areas in the West and Midwest were joined, and moderate drought had spread throughout the South and into eastern Texas. Severe drought continued in New England, and parts of the mid-Atlantic coast were also affected. By August, more than 35 percent of the Nation was experiencing severe to extreme drought.

Dry conditions moderated during the fall and winter months, as precipitation returned to normal for some areas and water demand subsided. By May 1989, the drought area was reduced to < 20 percent but quickly increased to nearly 30 percent by late summer. The most severely affected areas were California, Nevada, Arizona, Utah, and Wyoming, and parts of Colorado and New Mexico. Portions of the Pacific Northwest were also affected. The drought that had occurred in the Midwest and Northern Plains States in 1988 shifted south and west in 1989 to affect Kansas, eastern Nebraska, Iowa, and northern Missouri. For the most part, drought conditions in the Southeast, mid-Atlantic, and New England States disappeared. The area in severe to extreme drought leveled off at about 25 percent in 1990 and continued at that level through 1991. The principal areas affected were the Western States and portions of the northern Great Plains. A significant decline in the drought area occurred in early 1991 (to < 10 percent of the

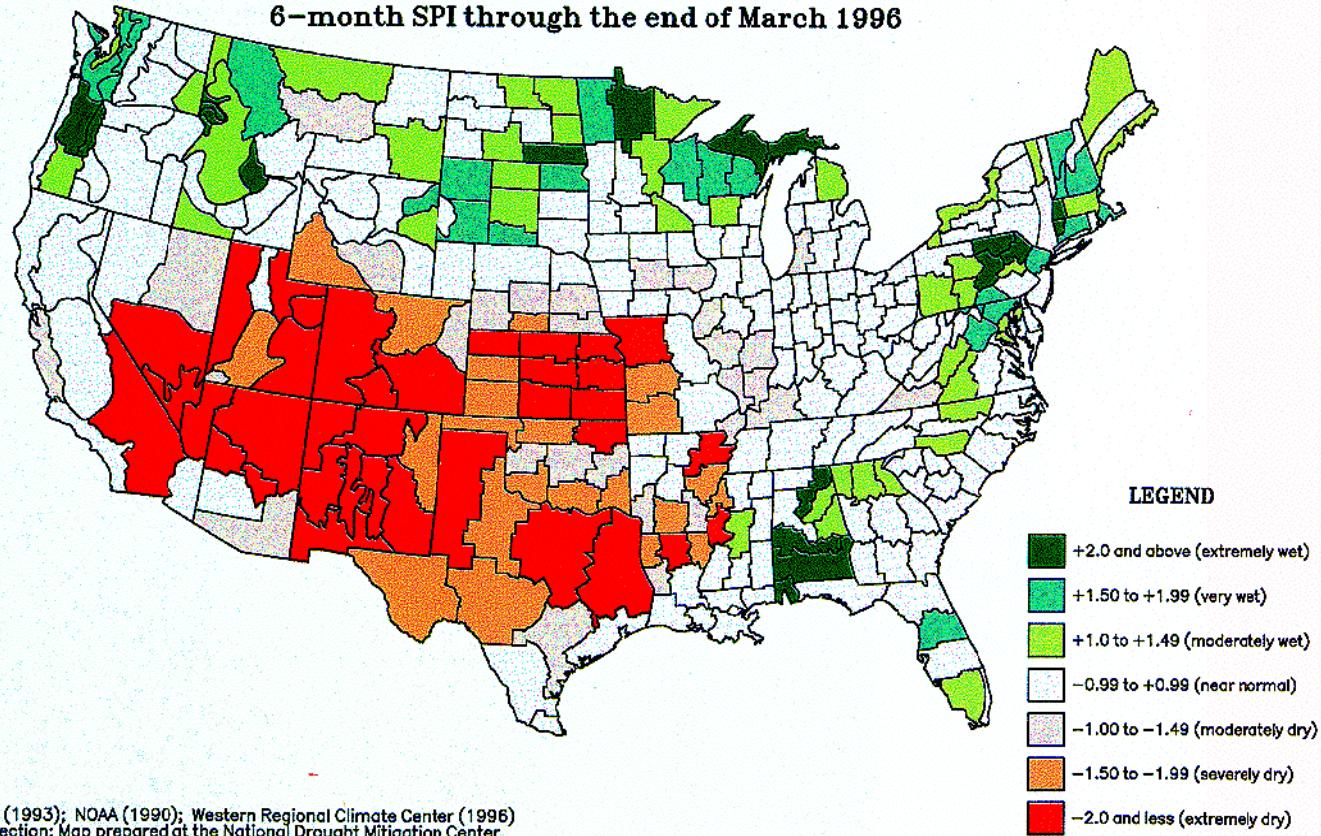
Nation). It peaked at 15 percent in July 1991, rising slightly to about 17 percent in July 1992. Again, the drought area was confined mainly to the Western States, including portions of the western Great Plains.

Drought conditions abated by mid-1993 for virtually all parts of the Nation. Portions of the Western States experienced what they believed to be an end to the drought that had been ongoing since 1986. However, much below normal winter precipitation over most of the western region resulted in the return of severe to extreme drought conditions in 1994. By May, extreme drought extended from California and the Pacific Northwest to western Nebraska and northern Colorado. During 1995, drought conditions were widely scattered and principally in the moderate category for most of the Nation. The primary areas of concern were the Northeast, portions of the Southeast, and portions of west Texas and eastern New Mexico. The wet winter of 1995-96 in the Northeast effectively ended concerns about an inadequate water supply in this region during 1996.

The drought that affected western Texas and New Mexico in 1995 expanded into southern California, Arizona, and New Mexico and parts of Nevada, Utah, Colorado, Texas, Oklahoma, Kansas, and Nebraska in 1996. In April, most of the drought area of the Southwest and Great Plains regions was classified in the moderate category (PDSI between -2.0 and -2.99), with only small areas classified in severe or extreme drought. By May, the PDSI showed intensified drought in this region, including most of the climatic divisions from southern California on the west to Arkansas and Louisiana on the east and portions of Colorado, Kansas, and Nebraska on the north. By mid-May, large areas were classified in the extreme drought category (PDSI  $\leq$  -4.0); these areas continued to expand in spatial extent through the early part of July.

There was considerable contrast between the SPI and PDSI maps during the spring months in characterizing the severity of the dry conditions. Since SPI maps can be calculated at various time scales, these maps can be tailored to reflect the appropriate time or duration period, starting with the month when precipitation deficiencies first begin to occur or to reflect a seasonal or water year perspective. A good example is the 6-month SPI map (figure 7) through the end of March 1996 (October 1995 to March 1996) and the March 30, 1996, PDSI map (figure 8). The SPI map depicts a large area from southern California and southern Nevada to western Missouri, Arkansas, and Louisiana in the severely to extremely dry category. SPI values of  $\leq$  -2.0

# STANDARDIZED PRECIPITATION INDEX (By Climatic Division) 6-month SPI through the end of March 1996



SOURCE: McKee et al. (1993); NOAA (1990); Western Regional Climate Center (1996)  
Albers Equal Area Projection; Map prepared at the National Drought Mitigation Center

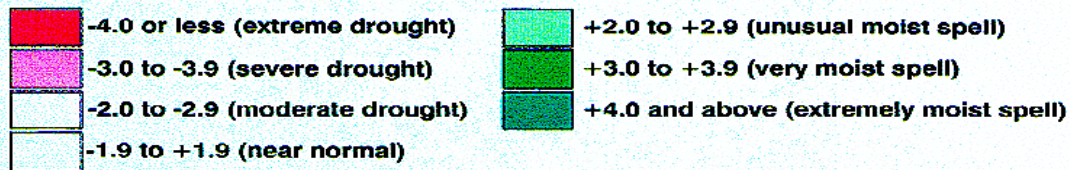
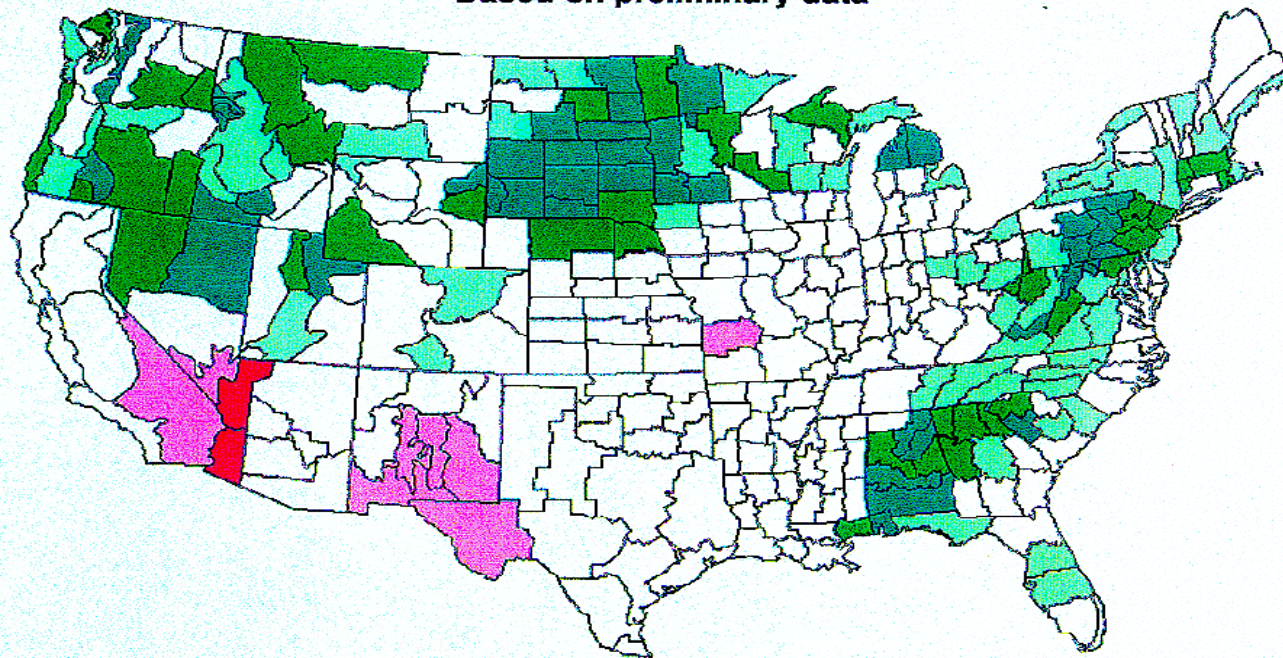
Figure 7.—Six-month SPI map for the end of March 1996 (representing the period October 1995 through March 1996).



## Drought Severity Index by Division (Long-Term Palmer)

March 30, 1996

Based on preliminary data



Climate Prediction Center, NOAA

Figure 8.—Palmer Drought Severity Index map, March 30, 1996.

would be expected to occur about 2.3 percent of the time, or about 1 year in 50. The severity of this emerging drought was already quite apparent on this SPI map, but not on the PDSI map. Early identification of emerging drought conditions is one of the key elements of an effective response plan because it allows decisionmakers at various levels to take more timely action. As the summer progressed, the States in the drought-stricken region and various Federal agencies became more aware of the virtues of the SPI and, as a result, these maps were often used in conjunction with the PDSI in routine climatic assessments by the National Weather Service and others.

### **State-Level Drought Planning: Current Status**

The number of States with drought plans has grown from 3 in 1982 to 28 in 1996 (figure 9). In 1991, 23 States had drought plans (Wilhite, 1991a). In addition to the States that now have plans, five States (Alabama, Oklahoma, Louisiana, Texas, and New Mexico) are at various stages of plan development. Texas undertook a comprehensive feasibility study in 1994 to consider an appropriate drought management plan (Water Demand/Drought Management Technical Advisory Committee, 1994). This study recognized the need for a Statewide plan and recommended the development of a drought planning and response framework as part of the State water plan. No action on this recommendation had taken place before the 1996 drought. In response to the 1996 drought, Oklahoma has initiated long-term drought planning activities, and New Mexico is seeking legislative funding and authority to develop a drought plan. Alabama and Louisiana initiated drought planning efforts before the 1996 drought. Two additional States allocate drought planning authority to regional (Florida) or local (California) authorities. Constraints to plan development were discussed by Wilhite and Easterling (1987), Wilhite (1992), and Wilhite (1996). Although the increase in the number of State drought plans is an extremely positive sign, these plans are still largely reactive (i.e., drought response versus drought mitigation plans), treating drought in an emergency response mode.

This pattern of State-level drought planning is quite complex and cannot be explained adequately on the basis of drought climatology alone. A State's decision to develop (or not to develop) a drought plan is based on specific climatological, political, economic, environmental, and demographic factors. Wilhite and Rhodes (1994) constructed a typology of State behavior in an attempt to explain the pattern of drought plans that existed in the early 1990s and found that social, political, and institutional influences may be as



States' concerns about Federal intrusion into State-level water resource planning and water rights, and some States' early experiences in working with the newly formed FEMA. Issues such as these may have contributed to an increased awareness of the value of drought planning within some State Governments. In the past decade, States have also been able to consult model drought plans (Western States Water Council, 1987; Wilhite, 1991b) and the growing number of State plans as a guide to the planning process.

The basic goal of State drought plans is to improve the effectiveness of State response efforts by enhancing monitoring and early warning, impact assessment, and preparedness, response, recovery, and mitigation programs. These plans are also directed at improving coordination within agencies of State Government and between State and Federal Government. The growth in the number of States with drought plans suggests an increased concern about the potential impact of extended water shortages and an attempt to address those concerns through planning. In the United States, States are clearly the policy innovators for drought management (Wilhite, 1991a), in contrast to Australia, where the Federal Government has provided most of the leadership, in concert with the States, for the development of a national drought policy (White et al., 1993). Drought plans are the foundation for improved drought management in the United States. The Federal Government should provide incentives for all drought-prone States to develop a plan that seeks to reduce the risks associated with extended periods of water shortage.

State drought plans take many forms. Some concentrate largely on impacts in one principal sector (e.g., agriculture, municipal water supply), while others attempt to address a full range of impacts within the State. One of the first States to develop a drought plan was Colorado. This plan was developed in 1981 at the request of the governor and is quite comprehensive. Since development, the plan has undergone revisions to improve the State's capacity to deal with extended periods of water shortage. The Colorado Drought Response Plan is administered by the Office of Emergency Management under the authority of the Colorado Natural Hazards Mitigation Council (Truby and Boulas, 1994).

The development of the Colorado drought plan was prompted by the State's susceptibility to drought and the desire to effectively and systematically deal with short- and long-term drought problems. Like its neighboring States, Colorado suffered through years of drought during both the 1930s and 1950s. In 1976 to 1977, a severe drought, mainly during the winter months, had an immense impact on the State, particularly the State's skiing industry,

causing severe economic impacts Statewide. When drought conditions again developed during the spring and summer in 1981, the governor initiated the development of a comprehensive State drought plan. The plan was updated in 1986 and again in 1990 (Colorado Office of Emergency Management, 1990). Maintaining an effective drought plan is important, as a rapidly growing population continues to increase demands on Colorado's water and other natural resources.

The Colorado plan is effective because it incorporates three primary components: a monitoring system, an impact assessment system, and a response system. The State is currently attempting to give greater emphasis to mitigation in its plan (Truby and Boulas, 1994). The responsibility for monitoring the availability of water resources is given to the Water Availability Task Force. This task force makes monthly assessments and projections of snowpack, soil moisture levels, reservoir and groundwater levels, precipitation, temperatures, and streamflow from data collected by numerous State and Federal agencies. This information can provide "early warning" of developing drought conditions to help the State prepare for a potential drought situation. Activation of the drought plan is triggered by the values of three indices: modified PDSI, Surface Water Supply Index, and the SPI.

The assessment system of the drought plan comprises eight different impact task forces covering the following water-related areas: municipal water, wildfire protection, agricultural industry, tourism, wildlife, economic, energy loss, and health. The goal of each task force is to identify existing and potential drought-related problems and assess possible impacts on society. Each task force is activated based on criteria specifically identified within the plan. Members of the task force are representatives from agencies directly involved with the issue. A final task force, called the Review and Reporting Task Force, is responsible for coordinating all assessments from the impact task forces and reporting this information to policymakers, media, and others.

The response system is designed to deal with the unmet needs identified by the specific task forces. Local responses are encouraged, but State action is taken when local capabilities are exceeded. The agency most closely associated with the appropriate response is assigned the responsibility to take action and enlist the cooperation of other agencies as necessary. These lead agencies are identified in the plan. For complex emergency responses, an interagency coordinating group is established.



Colorado has determined that it is important to have specific criteria established and responses clearly identified so that as a drought begins, the State can immediately begin to cope with the situation. Colorado's drought plan also calls for a postdrought evaluation. Suggestions made in these evaluations can be incorporated into the plan to help mitigate the impacts from future droughts.

### **Lessons From Recent Droughts: State-Level Mitigation Tools**

Wilhite (1993a) recently reviewed ongoing and developing Federal, interstate, and State drought mitigation technologies, programs, and policies in the United States. This study was based on the assumption that the roles of Federal and State Governments in drought mitigation needed to be reexamined, given the severity of drought experienced in the United States between 1986 and 1992; the economic, social, and environmental costs associated with these droughts; and the mitigation actions and policy efforts underway at all levels of government. One of the goals of the study was to identify opportunities to improve the effectiveness of drought mitigation efforts by the Natural Resources Conservation Service of the U.S. Department of Agriculture and other Federal agencies. A premise of this study was that the Nation's ability to cope with and manage water shortages resulting from drought would only be improved if an integrated approach within and between levels of government, involving regional organizations and the private sector, where appropriate, were adopted.

This section of the paper presents emerging drought assessment and mitigation technologies employed by State Government in recent years to lessen the effects of severe drought. Numerous innovative institutional arrangements were introduced during this period to manage water more effectively and efficiently in response to drought and increased demand. These data were collected through a survey of States and key Federal agencies with responsibility for the management of water and other natural resources. The survey was directed at specific drought mitigation actions taken or programs adopted during the period from 1986 to 1992, a period with a high incidence of drought in the West.

Mitigation is defined in several ways in the natural hazards literature. Hy and Waugh (1990) referred to mitigation as activities that reduce the degree of long-term risk to human life and property. These actions normally include insurance strategies, the adoption of building codes, land-use management, risk mapping, tax incentives and disincentives, and diversification. Drought is not often directly responsible for loss of life, and its impacts are largely

nonstructural. Therefore, this definition is not appropriate in this case. For the purpose of assessing mitigative actions specific to drought, this definition was modified as follows: short- and long-term actions, programs, or policies implemented in advance that reduce the degree of risk to people, property, and productive capacity.

In the study referred to above (Wilhite, 1993a), the survey instrument purposely did not define the term "mitigation." States were given flexibility to define mitigation by including actions or activities that they felt were appropriate. However, the definition given above was used to help understand and cluster the actions and activities reported by States. Mitigation activities identified by States and/or local municipalities during recent droughts were diverse, reflecting regional differences in impacts, legal and institutional constraints, and institutional arrangements associated with drought plans. The diversity in responses was also related to the wide range of State agencies with principal authority for drought planning and mitigation (e.g., agriculture, natural resources, water resources, emergency or disaster management).

State mitigation actions used to address issues during recent droughts are clustered into nine primary areas in table 1. These actions represent a full range of possible mitigative actions, from monitoring and assessment programs to the development of drought contingency plans. Some of the actions included were adopted by many States, while others may have been adopted only in a single case. It is clear, however, that the existence of a drought contingency plan facilitated the timely adoption and implementation of many of these mitigation actions.

Assessment programs adopted by States range from developing improved criteria or triggers for the initiation of specific actions in response to drought to establishing new data collection networks. Automated networks such as those that exist in Nebraska, California, and Oklahoma have significantly improved the State's monitoring capability. One of the three critical components of a drought plan is a comprehensive early warning system. Parameters that must be monitored to detect the early onset of drought include temperature and precipitation, streamflow, reservoir and groundwater levels, snowpack, and soil moisture. Each of these parameters represents different components of the hydrologic system and, therefore, impact sectors (e.g., agriculture, energy, transportation, recreation and tourism). To assess emerging drought conditions, these data must be

*State-Level Drought Planning: Current Status*

Table 1.—Drought-related mitigative actions taken by States during recent droughts

Category	Specific action
Assessment programs	Developed criteria or triggers for drought-related actions
	Developed early warning system, monitoring program
	Conducted inventories of data availability
	Established new data collection networks
	Monitored vulnerable public water suppliers
Legislation/public policy	Prepared position papers on public policy issues
	Examined water rights statutes for possible modification during water shortages
	Passed legislation to protect instream flows
Water supply augmentation/development of new supplies	Issued emergency permits for water use
	Provided pumps and pipes for distribution
	Proposed and implemented program to rehabilitate reservoirs to operate at design capacity
	Undertook water supply vulnerability assessments
	Inventoried self-supplied industrial water users for possible use of their supplies for emergency public water supplies
Public awareness/education programs	Inventoried and reviewed reservoir operation plans
	Organized drought information meetings for the public and the media
	Implemented water conservation awareness programs
	Published and distributed pamphlets to individuals, businesses, and municipalities on water conservation techniques and agricultural drought management strategies
	Organized workshops on special drought-related topics
Technical assistance on water conservation	Prepared sample ordinances on water conservation for municipalities and domestic rural supplies
	Provided advice on potential new sources of water
	Evaluated water quantity and quality from new sources
	Advised water suppliers on assessing vulnerability of existing supply system
	Recommended the adoption of water conservation measures to suppliers

*Improving Drought Management in the West: The Role of Mitigation and Preparedness*

Table 1.—Drought-related mitigative actions taken during recent droughts (continued)

Category	Specific action
Demand reduction/water conservation programs	Established stronger economic incentives for private investment in water conservation
	Encouraged voluntary water conservation
	Improved water use and conveyance efficiencies
	Implemented water metering and leak detection programs
Emergency response programs	Established alert procedures for water quality problems
	Stockpiled supplies of pumps, pipes, water filters, and other equipment
	Established water hauling programs for livestock from reservoirs and other sources
	Compiled list of locations for livestock watering
	Established hay hotline
	Provided funds for improvement of water systems, developing new systems, and digging of wells
	Provided funds for recovery programs for drought and other natural disasters
	Lowered well intakes on reservoirs for rural water supplies
Water use conflict resolution	Extended boat ramps and docks in recreational areas
	Acted to resolve emerging water use conflicts
	Negotiated with irrigators to gain voluntary restrictions on irrigation in areas where domestic wells were likely to be affected
	Established a water banking program
	Clarified State law regarding sale of water
	Clarified State law on changes in water rights
	Suspended water use permits in watershed with low water levels
Investigated complaints of irrigation wells interfering with domestic wells	
Drought contingency plans	Recommended to water suppliers the development of drought plans
	Established Statewide contingency plan
	Evaluated worst-case drought scenarios for possible further actions

integrated to provide a comprehensive snapshot of water availability and outlook. Many recommendations for the development of a national drought watch (Riebsame et al., 1991) or integrated climate monitoring system (U.S. Congress, U.S. Congressional OTA, 1993; Wilhite and Wood, 1994; FEMA, 1996) have been offered, but not implemented. Some States have also undertaken vulnerability assessments of public water supplies in conjunction with drought planning efforts. This is an especially critical issue in States with many small water supply systems that may be quite sensitive to extended periods of water shortage. It is important to identify vulnerable systems in advance so that adequate mitigation measures can be adopted.

Legislative actions included the passage of measures to protect instream flows and guarantee low-interest loans to farmers. Low-interest loans, a common Federal response to drought, are not generally State financed. Many States have been reexamining aspects of water rights doctrine in response to growing water use and associated conflicts. Water banks have been used in some States (e.g., California) as a means of temporarily modifying water allocation procedures during water shortages. The California Drought Water Bank program is an example of an innovative and successful mitigation action (California Department of Water Resources, 1992). This program was created in 1991. It allowed the Department of Water Resources to acquire water in three ways: (1) by purchasing water from farmers who chose not to irrigate; (2) by purchasing surplus water from local water districts; and (3) by paying farmers or water districts to use groundwater instead of surface water. MacDonnell et al. (1994) present a review of water banking in the West.

Augmentation of water supplies during recent droughts included rehabilitating reservoirs to operate at design capacity and reviewing reservoir operation plans. Cities also worked with self-supplied industrial users on programs to reallocate some water for emergency public water supplies.

One of the key responsibilities of State Government during periods of drought is to keep the public aware of the severity of the situation through timely reports. These reports must provide a clear rationale for mitigative actions that are being imposed on either a voluntary or mandatory basis. During recent droughts, States organized informational meetings for the media and the public, implemented water conservation awareness programs, prepared and distributed informational materials, and organized workshops on drought-related topics. Sample ordinances on water conservation were also prepared and distributed to municipalities and rural suppliers.

Most States lack the financial resources necessary to provide drought relief to individual citizens during times of emergency. However, it is often within the mission and capacity of State agencies to provide technical assistance to municipalities and others. During recent droughts, States assisted by providing advice on potential new sources of water and evaluating the quality and quantity of those supplies. Agencies also assisted municipalities in assessing the vulnerability of water supply systems. States encouraged the adoption of voluntary water conservation measures and established stronger economic incentives for water conservation within the private sector. Water metering and leak detection programs were implemented.

Some would not consider emergency response programs as a mitigative action; however, if these measures are implemented to reduce the risk of future impacts or as part of a long-term mitigation program, they represent a proactive approach to drought management. State responses included a wide range of measures, such as lowering well intakes on reservoirs for rural water supplies, establishing water hauling programs for livestock, extending boat ramps in recreational areas, and creating a tuition assistance program to enable farmers to participate in farm management classes.

Conflicts between water users increase during water-short periods. Timely intervention to resolve these conflicts will become increasingly necessary as demands on limited water supplies continue to expand in number and complexity. The best approach is to anticipate these conflicts well in advance of drought and initiate appropriate actions to avoid conflict. Many of the actions taken focused on the growing conflicts between municipal and agricultural water use.

The growing number of States with drought plans is an indication of greater concern about the impacts of drought and the acceptance by States of the role that planning can play in reducing some of its most adverse effects. The optimal time to plan for drought is during nondrought periods; however, considerable progress in establishing a basic response framework is often accomplished during the period of peak severity, as occurred in several drought-stricken States in 1996. The challenge is to transform this framework into a response/mitigation plan during the postdrought period. A brief window of opportunity usually exists to initiate a longer-term mitigation program between the panic stage of the hydro-illogical cycle at the peak of drought severity and the beginning of the apathy stage when rainfall returns to normal. Several States in the Southwest and southern Great Plains are

attempting to direct the interest in this past summer's crisis and direct it toward a longer-term planning process.

Many of the mitigative programs implemented by States during recent droughts can be characterized as emergency or short-term actions taken to alleviate the crisis at hand, although these actions can be successful, especially if they are part of a preparedness or mitigation plan. Other activities, such as legislative actions, drought plan development, and the development of water conservation and other public awareness programs, are considered actions with a longer-term vision. As States gain more experience assessing and responding to drought, future actions will undoubtedly become more timely and effective and less reactive. Viewed collectively, the mitigative actions of States in response to recent drought conditions are numerous, but most individual State actions were quite narrow. In the future, State drought plans need to address a broader range of mitigative actions, including provisions for expanding the level of intergovernmental coordination. One of the goals of the NDMC is to facilitate this process. Improved coordination will require a greater commitment by Federal agencies to work together and with States to promote an integrated approach to drought planning. Coordination at the Federal level will likely require the establishment of an interagency task force, as recommended by the U.S. Congressional OTA (1993).

## **Integrating Drought Management and Water Policy**

In the United States, the Federal Government became the principal player in the provision of drought relief during the 1930s in response to a drought that was nearly nationwide in extent and coexisted with severe economic conditions (Wilhite, 1983). Before the 1930s, assistance was provided primarily by the private sector (e.g., churches, Red Cross), but the level of assistance required during the 1930s far exceeded the response capacity of this sector. The Federal Government has continued to be the principal provider of drought assistance during subsequent drought events, most notably the 1950s in the Southwest, southern plains, and Midwestern States; the 1960s in the Northeast; the mid-1970s in the Midwest and Western States; and the recent series of drought years beginning in 1986. More than \$7 billion in drought relief was provided by the Federal Government during the period from 1974 to 1977 (Wilhite et al., 1986); nearly \$5 billion was provided in 1988 (Riebsame et al., 1991). Until recently, State Government assumed a relatively passive role in drought management. States have now

assumed a greater responsibility for drought planning, but drought relief remains largely a Federal responsibility.

Although Federal drought assistance programs in recent decades have been directed increasingly toward short-term or emergency assistance programs, earlier response efforts (i.e., the 1930s and 1950s) were characterized by a combination of both short- and long-term assistance programs. For example, in response to the 1930s drought, the Soil Conservation Service (SCS)<sup>3</sup> was formed to develop and promote soil and water conservation techniques nationwide, but with special reference to the Dust Bowl area of the Great Plains. The Great Plains Conservation Program was created following the severe drought of the early to mid-1950s to help farmers in the region preserve the natural resource base. In contrast, the Federal response effort in 1977 was characterized by 40 separate emergency drought assistance programs that were administered by 16 different Federal agencies (General Accounting Office, 1979). The administration of these programs was criticized by the GAO as inefficient and poorly coordinated. In 1988, Federal drought legislation in the form of grants and low-interest loans constituted most of the \$5 billion authorized by Congress to deal with the severe drought conditions that affected more than 40 percent of the Nation. The funds allocated by Congress in response to both the mid-1970s and 1988 drought can best be categorized as postimpact government interventions that did little, if anything, to reduce the Nation's underlying vulnerability to drought. In the future, the emphasis of Federal programs should be on risk management in conjunction with a systematic postdrought evaluation of the effectiveness of the preparedness and response effort.

Postdrought evaluations or audits are not routinely completed in the United States. However, following the severe droughts of 1976 to 1977 and the demonstrated inability of Federal Government to adequately cope with the problems that emerged, scientists and policymakers expressed considerable concern about the inefficiencies of this effort and repeatedly issued "calls for action" for the development of drought plans, including the development of a national drought policy and plan. These calls include recommendations from the Western Governors' Policy Office (1978), General Accounting Office (1979), National Academy of Sciences (1986), Great Lakes Commission (1990), American Meteorological Society (Orville, 1990), and Interstate Council on Water Policy (1987; 1991). In light of a possible increase in the frequency and severity of extreme events in association with changes in climate, an Environmental Protection Agency report (Smith and Tirpak,

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<sup>3</sup> Since completion of this study, the Soil Conservation Service of the U.S. Department of Agriculture has been reorganized as the Natural Resources Conservation Service.



1989) called for the development of a national drought policy to coordinate Federal response to drought.

In addition to these "calls for action," several studies completed in the late 1970s, 1980s, and 1990s evaluated specific response efforts and offered recommendations for improving future drought management in the United States. The recommendations emanating from these studies placed greater emphasis on deriving Federal initiatives to address many of the problems and issues identified, although the roles of State Government, regional organizations, and the private sectors were not ignored. A content analysis of the following studies was completed for this report: General Accounting Office (1979), Wilhite et al. (1986), Grigg and Vlachos (1989), Riebsame et al. (1991), Wilhite (1993a), Office of Technology Assessment (U.S. Congress, OTA, 1993), Wilhite and Wood (1994), and FEMA (1996). The goal of this analysis was to identify common threads or themes from these studies that would reduce the impact of future droughts and improve response efforts. The content of these studies is summarized below.

- **General Accounting Office** (*Federal Response to the 1976 to 1977 Drought: What Should be Done Next?*)

The General Accounting Office (1979) characterized the response programs implemented in 1976 to 1977 as largely untimely, poorly coordinated, and inequitable. They found that assistance provided by Federal agencies to farmers, communities, businesses, and water user organizations was available too late to lessen the effects of drought. GAO recommended that Congress direct the four principal agencies responsible for administering relief programs in 1976 to 1977 (i.e., Departments of Agriculture, Interior, and Commerce, and the Small Business Administration) to consider the problems identified and formulate a national plan to provide future assistance in a more "timely, consistent, and equitable manner." Plan development issues included identifying the respective roles of each agency to reduce duplication and overlap, legislation needed to more clearly define those roles, and standby legislation that might be necessary to allow for more timely response to problems associated with drought. GAO suggested that effectively implementing a national plan required establishing uniform criteria for determining "priorities for the type of projects to be constructed; eligibility of applicants; and interest rates, terms, and repayment requirements for loans." No action was taken on these recommendations.

- **Wilhite, Rosenberg, and Glantz** (*Government Response to Drought in the United States: Lessons from the Mid-1970s*)

Wilhite et al. (1986) confirmed the GAO findings and also concluded that the decisionmaking process for determining eligibility for drought assistance was seriously flawed. For example, the designation and revocation process for determining eligibility for the more than \$5 billion of disaster relief expended in 1976-77 was confusing and was not based on consistent, established criteria. In total, 16 Federal agencies administered 40 separate assistance programs in 1976-77. Wilhite et al. (1986) concluded, based on lessons learned during the 1976-77 response effort, that a more effective Federal response effort must address four basic issues. First, information on drought severity must be provided to decisionmakers and other users in a more timely manner. This requires better coordination of data collection efforts between Federal agencies, information sharing between and within levels of government, and improved delivery systems. Second, impact assessment procedures must be more reliable and timely. Better indices are required to capture the severity of drought, particularly in the spring planting period. Improved estimates of drought impact on yield would help trigger assistance to the stricken area; improved impact estimates are also important in other sectors such as fire protection, transportation, energy, and recreation and tourism. Third, objective and timely designation (and revocation) procedures are necessary to target assistance to drought areas. Decisions on drought disaster designations during 1977 were based largely on the Palmer Drought Severity Index, an index that is not appropriate for this application (Wilhite et al., 1986; Alley, 1984). Fourth, disaster programs must be more efficiently administered, and programs must match specific regional needs. In other words, the "one size fits all" approach of Federal drought assistance was not considered to be effective in addressing the needs of regions with different resource management issues. It was concluded that a national drought plan would help coordinate the activities of the Federal Government in responding to the effects of future droughts. It was also suggested that State Government and regional organizations should play a more active role in drought management and that those activities be coordinated between levels of government.

- **Grigg and Vlachos** (*Drought Water Management: Preparing and Responding to Drought*)

Grigg and Vlachos (1989) analyzed local, State, region (i.e., river basin), and Federal responses to the droughts of 1986 and 1988 and derived a series of "next steps" to improve future response efforts. These steps emphasized the importance of learning from previous experiences and treating drought management as a process rather than a discrete event. The study stressed the critical role of State Government in drought management and recommended that States evaluate existing plans and their effectiveness in responding to recent drought years. It was suggested that the Federal Government improve the analysis and integration of drought-related data and information and how this information is presented to various audiences. Grigg and Vlachos recommended that existing administrative structures be streamlined and communication between organizations be improved. This could be accomplished by a vertical restructuring between levels of government and a horizontal restructuring to achieve greater integration in water management. Better information on the origins and patterns of drought, the interrelationships of natural and human-induced water shortages, and the implications of climate changes on the frequency and severity of drought were considered necessary to improve understanding and decisionmaking. Grigg and Vlachos stressed the importance of contingency planning and using monitoring techniques to improve drought management to sustain the natural resource base. The challenge, in their view, was to make planning and management more effective within the current administrative and governmental system.

- **Riebsame, Changnon, and Karl** (*Drought and Natural Resources Management in the United States: Impacts and Implications of the 1987 to 1989 Drought*)

Riebsame et al. (1991) reviewed the climatology of the 1987 to 1989 drought and evaluated the impacts of and responses to this event. They concluded that the response effort was seriously deficient. It should also be noted that most of these deficiencies have been observed in previous droughts. Several critical issues were identified and recommendations were proposed to address these problem areas. These recommendations were to: (1) conduct a postdrought evaluation of the 1987 to 1989 experiences; (2) develop an improved drought watch system, linking Federal, State, and local agencies; (3) improve

the use of indices through an evaluation of their reliability in detecting emerging drought; (4) develop an integrated program of impact assessment for all primary sectors; (5) increase drought contingency planning to provide greater guidance to resource managers and others in response to extreme events; (6) develop improved recordkeeping on heat mortality and morbidity and conduct studies of the impact of drought on mental health; and (7) improve the delivery of information on drought and its impacts to users, especially in the business sector. Riebsame et al. (1991) suggested that because many of these recommendations were embodied in the National Climate Program Act of 1978, this legislation, if fully implemented, could serve as a vehicle to address many of these issues.

- **Wilhite** (*Drought Mitigation Technologies in the U.S.: With Future Policy Recommendations*)

Wilhite (1993a) completed a review of drought mitigation technologies that had recently been implemented in the United States in response to the series of severe drought years between 1986 and 1992. The primary goal of this study was to review and evaluate ongoing and developing Federal, interstate, and State drought mitigation technologies, programs, and policies as a basis for identifying opportunities to improve the effectiveness of future SCS drought mitigation initiatives. Although this study initially focused on SCS programming, the scope extended to all Federal agencies and other levels of government in an attempt to identify initiatives that would improve the Nation's ability to manage droughts through a more integrated approach within and between levels of government, involving regional organizations and the private sector where appropriate. Feedback from Federal and State Government and regional organizations was obtained from a series of survey instruments.

Six recommendations came from this study. First, it was recommended that a national drought policy and plan be developed to improve the effectiveness of future response efforts and the efficiency of resource allocation during times of water shortage. This action is intended to improve coordination by integrating planning activities within and between levels of government and reduce duplication between Federal agencies. Second, a national drought watch system was recommended to achieve a more comprehensive assessment of drought and other extreme climatic conditions. This system would

support and reinforce the tenets of a national policy and plan. Third, it was recommended that a national drought mitigation center be created to assist State and other levels of government in developing appropriate mitigation technologies. The center would also be responsible for establishing a clearinghouse that would serve as a resource for government, regional organizations, and the private sector for a broad range of drought-related information. Fourth, a review of all Federal drought relief programs was recommended to ensure their consistency with national drought policy. The goal of this action is to redefine emergency assistance available during periods of drought to guarantee that it provides adequate incentives for the adoption of proactive management and planning strategies that minimize risks associated with drought. Fifth, postdrought audits of previous response efforts must be conducted to identify the successes and failures of recent efforts. These audits would provide a rationale basis for recommending the continuation or discontinuation of assistance programs. Sixth, educational programs and training workshops that promote water conservation and management should be developed for all age groups and the media.

- **Office of Technology Assessment** (*Preparing for an Uncertain Climate*)

The OTA conducted a study (U.S. Congress, OTA, 1993) at the request of Congress to address how the United States can cope with projected changes in climate, given the high level of uncertainty about what the future climate is likely to be. This study sought to identify natural and managed natural resource systems at risk from climate change, how to incorporate the uncertainty of climate change into planning decisions, and whether the U.S. Global Change Research Program is providing information to decisionmakers in a timely manner. OTA based its assessment on six systems: coastal areas, water resources, agriculture, wetlands, Federally protected natural areas, and forests. The water section of the OTA report specifically addresses the issue of drought management and Federal initiatives that would improve future response and preparedness. OTA noted that a first step to improved water management would be improved management of extreme climatic events such as floods and droughts. One recommendation to improve drought management was to create an interagency task force to develop a national drought policy. Other recommended actions to improve water management were to provide the Bureau of Reclamation and the Corps of Engineers with greater administrative flexibility to manage reservoirs on a basinwide level

and promote water marketing as a means of facilitating water transfers. The use of new analytical tools for water modeling and forecasting, as well as demand management, were also recommended. OTA also recommended that the scope of the Western Water Policy Review Commission (Public Law 102-575) should be expanded to include a wide range of issues that are relevant to the issue of drought management. OTA also recommended that the nature of the review be expanded to address national water policy issues.

More specific to the issue of drought management, OTA suggested that a national drought policy and plan be created under Executive Order 12656, originally established to guide emergency water planning and management responsibilities of Federal agencies. The national drought policy and plan would be developed under the leadership of the interagency drought task force mentioned previously. OTA recommended that a national drought policy and plan identify "specific, action-oriented response objectives" and an implementation plan. Given the numerous Federal agencies with drought and water management responsibilities, a lead agency or the Office of the President would need to be appointed to direct this process. As part of this policy and plan formulation process, Federal agencies would be expected to review all drought assistance programs, including the identification of eligibility requirements for these programs and any overlapping responsibilities. A review of how financial resources are distributed to relief recipients and an evaluation of the timing and effectiveness of relief programs should also be included in this policy formulation process.

OTA recommended that three additional components should be part of a national drought policy and plan. These were adopting risk management practices to promote self-reliance and protect the natural and agricultural resource base, conducting postdrought audits to evaluate the effectiveness of these efforts, and developing a national drought watch system in support of a more proactive, anticipatory approach to drought management. The risk management measures that could be employed by Federal Government to reduce the impacts of future droughts are shown in table 2. These measures were divided into four categories--assessment, legislation and public policy, public awareness programs, and drought preparedness planning. The common thread through each of these categories is the need for planning at the State and national level, as well as by the private sector. The existence of a drought plan provides the institutional structure necessary to implement most of these measures.



Table 2.—Possible risk-management and risk-minimization measures the Federal Government could consider to lessen the effects of drought  
(Source: Wilhite, 1993c)

Category	Specific action
Assessment programs	Develop a comprehensive, integrated national drought-watch system
	Inventory data availability in support of a national drought-watch system
	Develop new indexes to assist in the early estimation of drought impacts in various sectors
	Establish objectives "triggers" for the phase-in and phase-out of relief and assistance programs
Legislation/public policy	Develop a national drought policy and plan
	Examine Federal land-use policies to ensure appropriate management of natural resources and consistency with national drought policy
	Review all Federal drought relief assistance programs, Federal crop insurance program, and other agricultural and water policies for consistency with national drought policy
Public awareness programs	Establish a national drought mitigation center to provide information to the public and private sectors
	Improve data information products and delivery systems to provide timely and reliable information to users
	Develop and implement water conservation awareness programs
Drought preparedness planning	Promote the establishment of comprehensive State drought plans
	Promote intergovernmental cooperation and coordination on drought planning
	Evaluate worst-case scenarios for drought management
	Evaluate the potential effects of climate change on regional hydrology and its implications on Federal and State water policies
	Promote the establishment of drought plans by public water suppliers
	Conduct postdrought audits of Federal drought assessment and drought response efforts



- **Wilhite and Wood** (*Drought Management in a Changing West: New Directions for Water Policy*)

In 1994, a conference was held to examine some serious questions about the future of western water and natural resources management and the region's growing vulnerability to extended periods of water shortages because of the sequence of drought years that occurred between 1987 and 1992 (Wilhite and Wood, 1994). Conference participants offered a series of recommendations to improve drought management and reduce vulnerability to future drought episodes. First, participants recommended the adoption of a national drought policy or framework that integrates actions and responsibilities between levels of government and promotes preparedness and mitigation. This policy should include actions that promote development of utility and locally based drought plans. Second, funds currently expended on drought relief should be reallocated to preparedness and mitigation programs. Third, region-specific drought policies should be developed, and the missions of Federal agencies should be modified, as necessary, to implement these policies. Fourth, FEMA should be encouraged to include drought planning and preparedness as a part of overall hazard planning at the State and local level. Fifth, human and technological resources should be redistributed within and between State and Federal agencies to promote collaborative institutional relationships that improve productivity and eliminate redundancy on drought and water policy and management issues. Sixth, an integrated climate monitoring system should be created to better detect emerging drought and other climate-related extreme events. Seventh, seasonal forecast skill for drought and water supply should be improved through increased support for research.

- **FEMA** (*Drought of 1996: Multi-State Drought Task Force Findings*)

In 1996, FEMA was asked to chair the Multi-State Drought Task Force to address the drought situation in the Southwest and Southern Great Plains States. The purpose of the task force was to coordinate the Federal response to drought-related problems in the stricken region by identifying needs, applicable programs, and program barriers. The task force was also directed to outline suggestions for improved drought management by offering both short- and long-term suggestions for national actions. To accomplish its objectives, a workshop was held in June 1996; it included representatives from

many Federal agencies, the drought-affected States, regional organizations, universities, and the Navajo Nation. The final report of this workshop (FEMA, 1996) divided short- and long-term recommendations and issues into three categories: policy, legislative, and executive branch. These recommendations are the product of intensive discussions and represent the opinions of all participating parties.

This discussion of the FEMA report will present only long-term issues and recommendations. First, participants recommended the development of a national drought policy based on the philosophy of cooperation with State and local stakeholders. They emphasized that this policy should be made now, even though "regional interests and States' rights advocates may occasionally throw up roadblocks." Participants emphasized the need for a contingency plan to help apply lessons from the past to future drought events. This policy should include a national climate/drought monitoring system to provide early warning of the onset and severity of drought to Federal, State, and local officials. This policy would also include an institutionalized organizational structure to address the issue of drought on a national scale. Second, the need for a regional forum to assess regional needs and resources, identify critical areas and interests, provide reliable and timely information, and coordinate State actions was suggested. It was suggested that multi-State and impact-specific working groups be established to identify critical needs. Third, FEMA was asked to include drought as one of the natural hazards addressed in the National Mitigation Strategy (FEMA, 1995), given the substantial costs associated with its occurrence and the numerous opportunities available to mitigate its effects. Fourth, the States strongly requested that a single Federal agency be appointed to coordinate preparedness and response to droughts. The States recommended that FEMA be given this responsibility; FEMA suggested that the U.S. Department of Agriculture should be the agency in charge, given its program responsibilities in agriculture and firefighting, often the first sectors affected.

## **Integrating Drought Management and Water Policy: New Directions**

The studies reviewed in the previous section of this report have many recommendations in common and help to define a series of next steps that the Federal Government should implement in concert with the States and others to reduce the risk associated with drought in the United States.

- **Create a National Drought Policy and Plan**

An interagency task force should be established to develop an integrated national drought policy and plan that emphasizes a preventive, anticipatory (i.e., risk management) approach to drought management and promotes self-reliance. The Australian National Drought Policy could be used as a model for the United States (White et al., 1993). The interagency drought task force would coordinate the activities of the Federal Government in responding to and mitigating the effects of drought. A lead Federal agency would need to be appointed to direct this effort.

The interagency task force should identify ways to streamline current administrative structures between levels of government (i.e., vertical) to improve communication and information flow and within levels of government (i.e., horizontal) to achieve a more integrated approach to water management (e.g., reservoir management on a basinwide scale).

The national policy or framework would integrate actions and responsibilities between all levels of government and would be developed through a participatory process. This policy and plan should lead to a more coordinated and timely response while concurrently promoting self-reliance. A national plan would include an institutionalized organizational structure to address drought on a national scale with mitigation and response policies and programs that are regionally appropriate.

Most funds expended on drought relief should be redirected to programs that encourage planning and mitigation or provide more timely and reliable information to decisionmakers.

The interagency task force should conduct a review of all Federal drought assistance programs to ensure that they are consistent with national policy.

- **Develop a National Climate Monitoring System**

A comprehensive, integrated national climate monitoring system (NCMS) would provide early warning of emerging drought and other climate-related (e.g., floods) extreme events. The goal of this system would be to integrate data from Federal and State data collection networks. It would include the following parameters: precipitation and temperature; streamflow; reservoir and lake levels; groundwater levels; snowpack; and soil moisture. Satellite remotely sensed data (e.g., Advanced Very High Resolution Radiometer) should be used to monitor vegetation stress to help derive early estimates of impacts.

Many States have created Statewide drought early warning systems as an important component of their drought plan. The NCMS would create a more efficient structure data collection and sharing on drought and water supply between State and Federal Government and a more timely and comprehensive water availability assessment. This system would be an invaluable resource for planners, managers, and policymakers nationwide in preparing for and responding to the broad range of climatic events that occur concurrently each year. This system would be an integral part of the national drought plan.

- **Incorporate Drought in the National Mitigation Strategy**

The National Mitigation Strategy (FEMA, 1995) includes all major natural hazards except drought. Steps should be taken, in conjunction with formulating a national drought policy and plan, to incorporate drought in this strategy.

- **Conduct Postdrought Audits of Federal/State Response Efforts**

Postdrought audits of Federal and State drought response efforts should be conducted to determine successes and failures; recommendations from these studies should be incorporated into national and State policies and plans.

- **Establish Regional Drought Forums**

Regional forums or councils should be established to consider drought-related issues on an ongoing basis to keep policies and plans current, share lessons learned, and avoid a return to the reactive approach to

drought management. This is an especially relevant issue in the drought-prone Western States and a principal recommendation of the Drought Task Force of the Western Governors' Association (1996).

- **Encourage Development of State Drought Mitigation Plans**

States should evaluate existing drought response plans and revise them to place greater emphasis on mitigation and to reflect national drought policy. The Federal Government should provide financial incentives and technical assistance for States to develop plans or revise existing plans.

Although the impacts of drought occur mainly at the local, State, and regional level, it is imperative for the Federal Government to provide the leadership necessary to improve the way this Nation prepares for and responds to drought. The Federal role should be one of facilitating the development of a national policy and plan through a participatory process involving all levels of government, regional organizations, the private sector, and other interests. The process recently adopted by the Australian Government to establish a national drought policy could be a model for the United States.

### **Australian National Drought Policy: A Model for the United States?**

Drought policy in the United States has not been stated explicitly by the Federal Government. What has evolved since the 1930s has been a de facto policy, one of reacting to, rather than preparing for, periods of water shortage. This crisis management approach, as discussed previously, has been ineffective, and drought relief does not support the sustainable use of natural resources. Unfortunately, the decision whether or not to provide drought relief has been based more often on political, rather than economic, reasoning. Without a clearly stated drought policy, no significant improvement in response efforts will occur in the United States.

It is strongly recommended that the United States follow the example of Australia in establishing an integrated national drought policy based on the principle of self-reliance and risk management (White et al., 1993). Although the Australian approach is focused strictly on agricultural drought, the principles of that policy are transferable to other sectors. According to Australian policy, drought is not considered to be a natural disaster, but instead, an integral part of a highly variable climate. Drought is considered one of many risks that farmers face in managing farm operations. The Federal Government now defines its role under this policy as assisting

farmers in coping with climatic variability through the provision of better and more timely information for improved decisions. The Federal Government is investing in improved monitoring systems and forecasting tools, research on risk avoidance for farmers, and improved decision support systems in support of this national policy.

The objectives of Australian drought policy are: (1) to encourage primary producers and other segments of rural Australia to adopt self-reliant approaches in managing for climatic variation, (2) to facilitate the maintenance and protection of Australia's agricultural and resource base during periods of increasing climatic stress, and (3) to facilitate the early recovery of agricultural and rural industries to levels consistent with long-term sustainable production. Given that drought is a normal and expected part of climate, under this policy, relief measures that protect farmers from climatic risks and/or support unsustainable farming systems are considered inconsistent with policy and are discouraged, except under exceptional circumstances (i.e., droughts of greater than 12-months' duration and a recurrence interval of 1 in 20 years). This policy incorporates incentives to encourage farmers to adopt management practices that accept drought as a routine course of business. The long-term goal of this policy is to increase productivity, improve the allocation of resources, and enhance self-reliance among farmers.

Adopting an approach to drought management modeled after Australia's national drought policy would dramatically change the way resources are managed in the United States. Given that previous attempts to mitigate drought in the United States have been largely unsuccessful, it seems clear that fundamental and sweeping program and policy changes must occur for the Nation to more adequately address the drought management problems that exist today. A national drought policy could provide a framework for States to follow in making their plans consistent and compatible with national goals for the sustainable use of natural resources.

## **Conclusions and Recommendations**

Water is an increasingly scarce resource in the Western United States. A comprehensive review of Federal activities in the West related to water allocation and use must address how these activities are affected (and will be affected) by the frequent occurrence of extended periods of severe drought. The Water Policy Review Advisory Commission is encouraged to accept the following basic premises as part of its review process. First, drought is a normal part of a highly variable climate in the West. Second, the economic,

social, and environmental impacts associated with drought in the region are significant and appear to be escalating at an accelerating pace. Third, the frequency and severity of meteorological drought will likely increase in response to changes in climate and accompanying changes in regional hydrology, further increasing future impacts. Fourth, the adoption of the principles of risk management (i.e., mitigation) in drought management in the West is fundamental to sustaining the quality of life and the environment in the region and Nation.

During the past decade in the United States, widespread and severe drought has resulted in an increased awareness of the Nation's continuing vulnerability to this creeping natural hazard. This experience has resulted in numerous initiatives by State and Federal Government to improve the timeliness and effectiveness of response efforts. Although some progress has been made, much remains to be done. For the most part, government continues to deal with drought in a reactive, rather than proactive, mode. The growth in the number of States with drought plans in the West and elsewhere is one positive sign that greater emphasis is now being placed on drought preparedness, although most State response continues to stress emergency assistance. States have developed and implemented a wide range of mitigation measures, but the shift from crisis management to risk management continues to be a difficult transition.

For this transition to be successful, the deficiencies of previous drought response attempts must be addressed in a systematic way. Creating a Federal interagency task force with the authority to develop and implement an integrated national drought policy and plan would represent an important first step. The task force must develop the objectives of a national policy in concert with extensive public involvement. This policy should promote the concept of risk management, although it cannot ignore the need for government assistance during extended periods of severe drought. However, this assistance must be consistent with national policy. The policy should promote self-reliance, while at the same time protecting the natural and agricultural resource base. The interagency task force should coordinate the drought-related activities of the Federal Government (i.e., forecasting, monitoring, impact assessment, response and recovery, and planning). This national policy should also incorporate incentives for all drought-prone States to develop plans that promote a more proactive, anticipatory approach to drought management. Lessons learned from previous drought response attempts need to be documented, evaluated, and shared with all levels of government through postdrought audits.

A critical component of a national drought policy and plan is an integrated national climate monitoring system to continuously track climatic conditions and anomalies and project water availability. The components of such a system are already in place but are divided among many Federal mission agencies. This monitoring system would provide the basis for the early detection of drought and other extreme climatic events, enabling planners, natural resource managers, and others to make more informed and timely decisions. The relatively small investment required to develop and maintain this system is justified, given the large benefits that would accrue through a reduction of impacts associated with droughts, floods, and other climate-related events.

Drought inflicts considerable pain and hardship on society. The impacts of contemporary droughts in the West have demonstrated this fact repeatedly over the past several decades. Drought illustrates, in innumerable ways, the vulnerability of economic, social, political, and environmental systems to a variable climate. It also illustrates the dependencies that exist between systems, reinforcing the need for improved coordination within and between levels of government.

Extended periods of normal or benign weather conceal the vulnerability of societies to climate variability, while drought exposes these sensitivities. Projected changes in climate because of increased concentrations of carbon dioxide and other atmospheric trace gases suggest a possible increase in the frequency and intensity of severe drought in the future. In the West, where the incidence of drought is high, any increase in drought frequency will further aggravate an already difficult situation. Coupled with increasing population and the associated rise in demand for water and other shared natural resources, there is a sense of urgency for reducing the personal hardships and economic and environmental impacts of drought.

### **Bibliography**

Alley, W.M., 1984. The Palmer Drought Severity Index: Limitations and Assumptions, in *Jour. Of Climate and Appl. Meteorol.* 23:1100-1109.

California Department of Water Resources, 1992. *Report to the California Water Commission*, Sacramento, California, May 1.

Colorado Office of Emergency Management, 1990. *The Colorado Drought Response Plan*, Denver, Colorado.

FEMA, 1995. *National Mitigation Strategy: Partnerships for Building Safer Communities*, Washington, DC.



- \_\_\_\_\_, 1996. *Drought of 1996: Multi-State Drought Task Force Findings*, Federal Emergency Management Agency, Region VI, Denton, Texas.
- General Accounting Office, 1979. *Federal Response to the 1976-77 Drought: What Should Be Done Next?* CED-79-26, Washington, DC, January.
- Great Lakes Commission, 1990. *A Guidebook to Drought Planning, Management, and Water Level Changes in the Great Lakes*, Great Lakes Commission, Ann Arbor, Michigan, 61 pp.
- Grigg, N.S., and E.C. Vlachos, 1989. *Drought Water Management: Preparing and Responding to Droughts*, International School for Water Resources, Colorado State University, Ft. Collins, Colorado.
- Houghton, J.T., G.J. Jenkins, and J.J. Ephraums (eds.), 1990. *Climate Change: The IPCC Scientific Assessment*, Cambridge University Press, New York.
- Hy, J.H., and W.L. Waugh, Jr., 1990. The Function of Emergency Management, W.L. Waugh, Jr., and R.J. Hy (eds.), Chapter 2, in *Handbook of Emergency Management: Programs and Policies Dealing with Major Hazards and Disasters*, Greenwood Press, New York.
- Interstate Council on Water Policy, 1987. *Statement of Policy 1986-87*, Interstate Council on Water Policy, Washington, DC. , 39 pp.
- \_\_\_\_\_, 1991. *Statement of Policy 1991-92*, Interstate Council on Water Policy, Washington, DC, 39 pp.

- MacDonnell, L.J., C.W. Howe, K.A. Miller, T.A. Rice, and S.F. Bates, 1994. *Water Banks in the West*, Natural Resources Law Center, University of Colorado, Boulder, Colorado.
- McKee, T.B., N.J. Doeskin, and J. Kleist, 1993. The Relationship of Drought Frequency and Duration to Time Scales, *Eighth Conference on Applied Climatology*, American Meteorological Society, Boston, Massachusetts.
- \_\_\_\_\_, 1995. Drought Monitoring with Multiple Time Scales, *Ninth Conference on Applied Climatology*, American Meteorological Society, Boston, Massachusetts.
- National Academy of Sciences, 1986. *The National Climate Program: Early Achievements and Future Directions*, Washington, DC, 55 pp.
- Natural Hazards Observer, 1996. Witt Announces FEMA Mitigation Plan, *Natural Hazards Observer* 20:10, Natural Hazards Information and Applications Center, University of Colorado, Boulder, Colorado.
- Orville, H.D., 1990. AMS Statement on Meteorological Drought, in *Bull. Of the Amer. Meteorol. Soc.*, 71:1021-1023.
- Palmer, W.C., 1965. Meteorological Drought, *Research Paper No. 45*, U.S. Weather Bureau, Washington, DC.
- Riebsame, W.E., S.A. Changnon, Jr., and T.R. Karl, 1991. *Drought and Natural Resources Management in the United States: Impacts and Implications of the 1987-89 Drought*, Westview Press, Boulder, Colorado, 174 pp.
- Smith, J.B., and D. Tirpak, 1989. *The Potential Effects of Global Climate Change on the United States*, Report to Congress, Environmental Protection Agency, Washington, DC.
- Truby, J.O., and L.A. Boulas, 1994. Formulation of a Mitigation System for Long-Term Drought in Colorado, *Drought Management in a Changing West: New Directions for Water Policy* (Proceedings of a Conference), IDIC Technical Report 94-1, University of Nebraska-Lincoln, 239 pp.

- U.S. Congress, Office of Technology Assessment, 1993. *Preparing for an Uncertain Climate, Volume 1, OTA-O-567*, U.S. Government Printing Office, Washington, DC.
- Water Demand/Drought Management Technical Advisory Committee, 1994. *Consideration of an Appropriate Drought Management Plan for the State of Texas*, Texas Water Development Board, Austin, Texas.
- Western Governors' Association, 1996. *Draft Strategy for Development of Western Drought Policies and Regional Response Plans*, Denver, Colorado.
- Western Governors' Policy Office, 1978. *Managing Resource Scarcity: Lessons from the Mid-Seventies Drought*, Institute for Policy Research, 78 pp.
- Western States Water Council, 1987. *A Model for Western State Drought Response and Planning*, Midvale, Utah, October.
- White, D.H., D. Collins, and M. Howden, 1993. Drought in Australia: Prediction, Monitoring, Management, and Policy, D.A. Wilhite (ed.), in *Drought Assessment, Management, and Planning: Theory and Case Studies*, Kluwer Academic Publishers, Boston, Massachusetts, 320 pp.
- Wilhite, D.A., and M.H. Glantz, 1985. Understanding the Drought Phenomenon: The Role of Definitions, in *Water International* 10:111-120.
- Wilhite, D.A., and W.E. Easterling, 1987. *Planning for Drought: Toward a Reduction of Societal Vulnerability*, Westview Press, Boulder, Colorado.
- Wilhite, D.A., N.J. Rosenberg, and M.H. Glantz, 1986. Improving Federal Response to Drought, in *Journal of Climate and Applied Meteorology* 25:332-342.
- Wilhite, D.A., 1983. Government Response to Drought in the United States: With Particular Reference to the Great Plains, in *J. of Climate and Appl. Meteorol.* 22:40-50.
- \_\_\_\_\_, 1991a. Drought Planning and State Government: Current Status, in *Bull. of the Amer. Meteorol. Soc.* 72: 1531-1536.
- \_\_\_\_\_, 1991b. Drought Planning: A Process for State Government, in *Water Res. Bull.* 27:29-38.

- \_\_\_\_\_, 1992. *Planning for Drought: A Guidebook for Developing Countries*, Climate Unit, U.N. Environment Program, Nairobi, Kenya.
- \_\_\_\_\_, 1993a. *An Assessment of Drought Mitigation Technologies in the United States*, Final Report to the Soil Conservation Service/USDA, IDIC Technical Report 93-1, University of Nebraska-Lincoln.
- \_\_\_\_\_, 1993b. Planning for Drought: A Methodology, Wilhite, D.A. (ed.), Chapter 6 (pp. 87-108), in *Drought Assessment, Management, and Planning: Theory and Case Studies*, Kluwer Academic Publishers, Boston, Massachusetts.
- \_\_\_\_\_, 1993c. Drought Management and Climate Change (contractor report), in *Preparing for an Uncertain Climate*, U.S. Congress, Office of Technology Assessment, vol. 1, OTA-0-567, Washington DC, U.S. Government Printing Office.
- \_\_\_\_\_, 1996. A Methodology for Drought Preparedness, *Natural Hazards* 13:229-252.
- Wilhite, D.A., and D.A. Wood, 1994. *Drought Management in a Changing West: New Directions for Water Policy*, IDIC Technical Report 94-1, International Drought Information Center, University of Nebraska-Lincoln.
- Wilhite, D.A., and S.L. Rhodes, 1994. State-Level Drought Planning in the United States: Factors Influencing Plan Development in *Water International*: 19:15-24.