US Army Corps of Engineers

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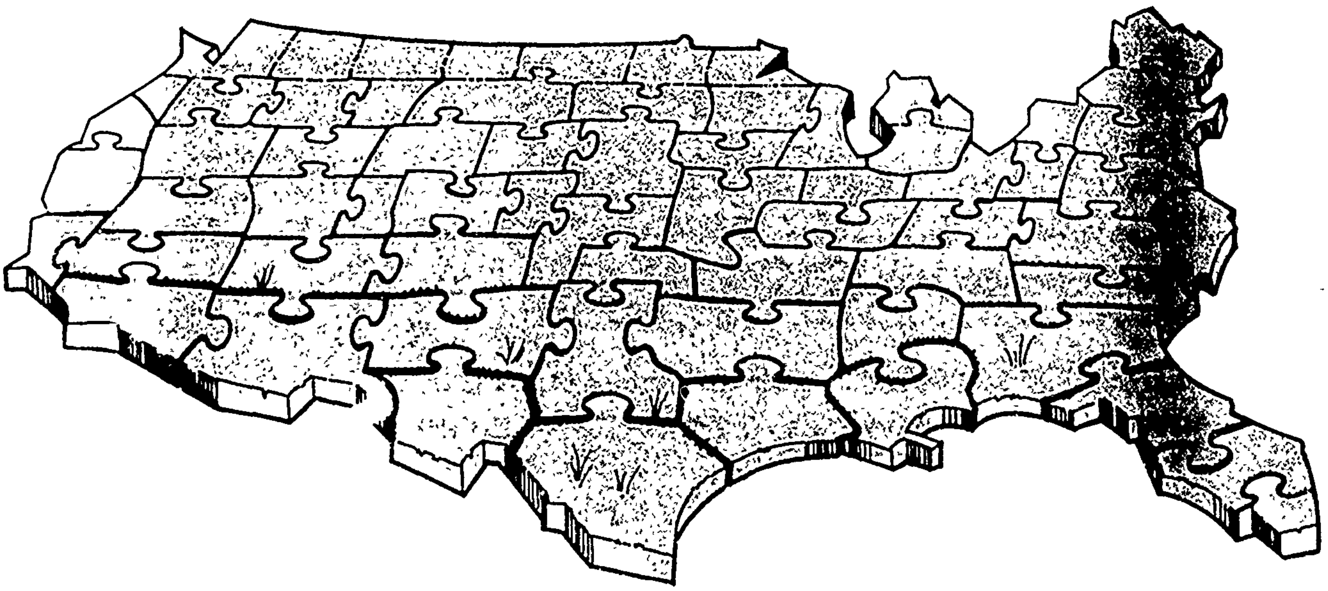
The National Study of Water Management During Drought

Report on the First Year of Study



May 1991

IWR Report 91-NDS-1

National Study of Water Management During Drought Reports

This report is the first of a series of reports which will be published during the study. Reports on two studies conducted under the aegis of the National Study of Water Management During Drought will be published in May 1991:

A Preliminary Assessment of Corps of Engineers Reservoirs, Their Purposes and Susceptibility to Drought (IWR Report 91-NDS-2). The Corps Hydrologic Engineering Center in Davis, California used its Reservoir Database Network to link databases on Corps reservoirs, with databases which are maintained by other agencies for precipitation, drought, temperature, evaporation, and streamflow, recreation, and population. Assessments were made for each Corps division.

An Assessment of What is Known About Drought (IWR Report 91-NDS-3). Planning Management Consultants, Ltd. critically reviews reported impacts of past U.S. drought, the factors that affect vulnerability, and the current state of preparedness throughout the U.S. The report also highlights some innovative approaches to drought preparedness throughout the U.S. that are now being used in parts responding to drought. Finally, the report suggests the areas where further research would be most productive.

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Reports may be ordered by writing (above address) or calling Arlene Nurthen, IWR Publications, at (703)-355-3042.

The National Study of Water Management During Drought

Report on the First Year of Study

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Policy and Planning Division
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Executive Summary

BACKGROUND

This is a report on the findings and recommendations from the first year of the National Study of Water Management During Drought. The study, conducted by the U.S. Army Corps of Engineers, with the help of the water management community, is a review of the way water is managed during drought in the United States. This report is a formal part of an ongoing dialogue within the water management and user community.

The systems for water management in this country are mature and sophisticated, but sometimes overly contentious and sometimes too inflexible. Although the nation is comparatively well served by its water management system, there are some areas where improvements could provide a more secure supply, better use, and greater efficiency. Like any mature system which already performs reasonably well, the next increment of performance will be more difficult to achieve, but not impossible. This report recommends a practical, step by step strategy for better serving the water needs of the U.S.

The impacts of drought differ regionally. The West is a mostly arid region, used to dealing with the specter of water scarcity; there the major issues are the reallocation of water to address changing demands, and Federal management and regulation in an appropriation law setting.

In the North Central states, water quality is a major concern, with some small communities now unable to drink the water in the ground beneath them. A second major concern for those along the Great Lakes is excessively fluctuating lake levels. In the Southeast, many users, such as hydropower, municipal water supply, and recreation, compete for water, whether the source is reservoir storage and releases or ground water extraction. Intense environmental concerns affect this competition for water, such in the Everglades region of South Florida. In the Northeast, the infrastructure for municipal water supply is aging and vulnerable; quantity and quality issues are intertwined. In many parts of the country, as in the Southeast, the problems are best characterized in terms of the competition among types of use for scarce water.

Water management during drought is an enormous field of endeavor. It is both a special case of water management in general, and an integral part of drought impact mitigation, which is dominated by issues such as crop subsidies, relief payments, and forest fire management.

Water management decisions are made using a variety of abstract models for engineering, law, economics, biology, and social science. The decisions extruded from any of these models tend to have the characteristics of the model as well as the reality being modeled.

Typically, several of these abstract models must be harnessed together to pursue the practice of water management during drought. That practice is guided by a hierarchy of principles starting with the U.S. Constitution, and it has many dimensions, including the different levels of government, the purposes for which water is managed, and the roles that water managers play (regulator, planner, etc.).

The meshing of this multi-dimensional practice with the substantial, hierarchical body of rules forms a *de facto* water management policy, but one which is more labyrinth than guiding path. The complexity and rigidity of the entire water management system, which is not managed (or very often studied) *as a system* is the principal national challenge to better water management during drought. There is widespread concern about our ability to solve problems because of the time, contentiousness, and cost involved in negotiating this labyrinth.

There is no clearly expressed national drought policy or plan, nor is there a consensus in the water management community about what that drought management plan or policy should be. A few influential groups have suggested alternatives which have neither been implemented nor rejected.

The primary objective of this study is to develop a strategy to improve water management during drought, but there will be no nationwide changes until there is sufficient support for specific policies or plans.

The strategy recommended here for better water management during drought is to engage the water management community in a number of case studies over the next three years which will not only work on different specific regional problems, but will serve as the basis for the formulation and testing of different approaches to the general question: How do we *want* water to be managed during drought?

At the end of this study we will have several case studies and topical studies from which a manual on how to prepare for drought will be written. In addition, we may be able to make recommendations for policy changes based on experiences. Specific conclusions and recommendations from the first year of study begin on the next page.

CONCLUSIONS

1. Much has been done in the United States to reduce vulnerability to drought since the great droughts of the 1930's. But the goal of minimal impacts is a moving target because demands can increase and diversify, and, as with all issues surrounding the human adaptation of the world to specific human purposes, there is a substantial debate about what constitutes success.

2. Future impacts of drought are likely to be more serious than the immediate impacts from the 1988 drought because in some areas, we had plentiful water and we had large stores of grain when the drought started. Many places in the country are *chronically ill prepared* for drought. These problems will be exacerbated if, as some studies suggest, global warming increases the severity and frequency of droughts in the U.S.

3. Most experts agree that better planning, better data, better analytical techniques, and a more coordinated, cooperative and communicative response would improve water management during drought.

4. No consensus exists within the water management community on a national strategy to improve water management during drought. Disagreements are based on differences in perspective, experience, and responsibilities. There is a limited amount of study devoted to the integration of the many pieces of this complex issue. There is also a resistance to strategy changes in a system as large and complex as the water management system.

5. No single conceptual model, in law, engineering, economics, the social or environmental sciences, encompasses the reality of drought. No single profession or institution can manage water during drought solely within its purview. A region interested in reducing the impacts of drought should find a way to effectively and efficiently include all these perspectives and concepts in its planning.

6. Regional differences are substantial, in needs, law, climate, and level of investment. National policies (to the extent that they will ever be spelled out) must reflect the diversity of situations within the 50 states.

7. The nation should find better ways to share success stories and technical advances among regions, despite the regional differences. This is especially true for overall drought preparedness strategies, water conservation, and demand forecasting. The collaborative problem-solving approach is not used enough.

8. The application of water conservation principles is spotty. The reduction of the demand for water is being used more and more often as an alternative to new supply, but when supply is considered adequate, the costs savings which are available (such as reduced treatment costs on a municipal level, and reduced energy costs on a household level) are often ignored. Techniques which estimate the effectiveness of proposed water conservation measures have been developed and tested, but are not widely enough used.

9. Some basic questions about drought preparedness are unanswered, such as "how big a drought should we plan for?", or, "how much is it worth to reduce our vulnerability?" Unlike floods and other natural disasters, droughts are difficult to plan for, based on specific scenario drought events. There are many significant variables to consider during a drought, and typically not enough is known about the recurrence intervals. Since there are often too many drought scenarios to consider, and uncertain levels of risk for each scenario, most drought planning is oriented towards a decision process.

10. Streamflow forecasting and risk-based decision-making techniques have the potential to provide water managers valuable tools with which to prepare for drought. However, application of this synthesis of models is not widespread.

11. Some regions have a greater need and a greater willingness to change than others, and the Corps is in a better position to help in some places than others. Regions which have recently gone through a serious drought, and regions in which the major users and managers believe that change could benefit everyone are more likely to rethink water management methods.

12. The Corps is more capable of helping a region plan for drought when the Corps already has the experience that comes from having an important planning or operating role in the region; it will only be successful in helping a region plan for drought when non-Corps water managers welcome Corps involvement.

13. Some changes are so fundamental that they cannot be rushed. Current laws and institutions are not ideally suited to managing current and future water management challenges, most water managers agree that what we have needs revision. But such fundamental changes tend to be resisted because no one can predict their ultimate effect, and current stakeholders might be hurt.

14. Funding and staffing for drought planning face stiff competition with other important concerns at all levels of government. Not enough is known about how to strategically prepare for droughts so that the maximum benefits can be derived from the minimum expenditures, these uncertainties come from the difficulty in quantifying expected values of benefits, and from difficulties in prioritizing the worth of types of solutions.

RECOMMENDATIONS

Based on the conclusions listed above, and consistent with the primary study objective to develop a strategy for improving water management during drought in this country, we offer the following recommendations:

1. Develop *Drought Preparedness Studies (DPS)* **during the remaining three years of the study in four river basis: the Kanawha (West Virginia), James (Virginia), Cedar/Green (Washington), and Marais des Cygnes-Osage (Kansas-Missouri).**

Each DPS will be designed to address a regional drought problem. Collectively, the DPS's will be used to develop a planning guide which other regions can use to prepare for drought. The DPS's will add to the water management community's experience with system management. These studies may provide opportunities to aid the development of national drought policies. The majority of the remaining time and funding of this study will be devoted to the conduct of these studies.

Each DPS will address the questions: *how does this region want to be positioned for future droughts? and what can the region do now to mitigate impacts of future drought?* All the perspectives associated with the problem of drought will be included in the strategy developing process.

Each study includes the formation of a study group representing water managers, users, and other interested parties. Points that will be addressed in each study include:

- development of a statement of goals and objectives which address the values and needs of all the participants;
- an assessment of vulnerability under the *status quo*;
- an evaluation of available data and technical tools;
- the development of a public involvement and education plan, legal and institutional reviews to determine if changes in those areas would contribute to the goals of the DPS;
- development of a plan for water management during drought under the new strategy; and
- formulation of a drought exercise program to maintain staff familiarity with drought issues and to assure that the strategy did not become dated as situations in the region changed. Drought preparedness efforts will not end when the studies are over.

Each DPS will be tailored to meet the needs of the region. Some studies will need more time and money on the development of an organization that brings stakeholders into negotiation. Others will concentrate on the development of technical tools and public involvement. Each will benefit from the success stories and technical advances that have been used elsewhere. The National Water Management During Drought Study will continue to develop the network of water managers nationwide who can both contribute to and study these regional efforts. State agency water managers, among others, will provide an important contribution to these studies.

2. Prepare a *National Drought Atlas.*

Not enough is known, and less is shared, about the probability that droughts of a certain duration or length will occur. That ignorance has significant planning consequences because no one knows how big a drought for which to plan. The Atlas will be a book of tables, charts and maps that illustrate historical drought in frequency terms that can be used as a source of information for drought planning. The frequencies of precipitation, Palmer indices (indices of soil moisture), and streamflow will be presented for all climatic regions of the United States for durations and areas appropriate to that region. The Atlas will be prepared jointly by those Federal agencies charged with the responsibility for these data: the National Oceanographic and Atmospheric Administration's National Climate Data Center for precipitation, and Palmer indices; the United States Geological Survey (USGS) for streamflow. Once published, the Atlas will outline the state of the art in the presentation of historic drought records. But because of the inherent difficulties in analyzing historical drought records and applying them to current planning, the Atlas will also expose what we do *not* know. As such, it will serve as a point of departure for regional frequency analyses and future research to improve on the state of the art.

Other information will be included in the Atlas. For example, available tree-ring records will be presented to supplement as much as possible the historic records. Also, discharges on regulated rivers will be examined to see if useable information can be presented, such as in the Tennessee Valley River Basin, where TVA has one-day minimum flow records.

3. Prepare Topical Studies.

Topical studies will be conducted in conjunction with four DPS's in the areas of planning methodologies, law, institutional analysis, engineering, economics, environment, other hard to quantify impacts, financial analysis, public involvement, negotiation and dispute resolution, risk assessment and management, and decision making. The aim of these studies will be to provide a basis for the selection and prioritization of the application of these tools for drought preparation.

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Report from the First Year of the National Water Management During Drought Study

SUBJECT

ACKNOWLEDGEMENTS

There is an implicit promise in the title "National Study of Water Management During Drought". The promise is that it will consider drought issues in all parts of America, and will reflect the range of thinking throughout the country on those issues. Who could know all that? Whose perspective is that broad? Those rhetorical questions explain why the Assistant Secretary of the Army for Civil Works asked Governors, the heads of other Federal agencies, regional and basin organizations, and the academic community for help at the outset of this study.

The response was strong and interested, and grows as this report on the first year of the study goes to press. Thanks are extended here to all of those outside the Corps, as well as the many Corps professionals throughout the country, who are helping fulfill the promise of a "national" study.

This report is a summary of the first year's activities of the National Study of Water Management During Drought, which is being conducted by the Corps of Engineers in cooperation with the U.S. water management community. The study team responsible for this report consisted of Mr. William Werick (study manager and principal author); Dr. Robert Brumbaugh and Dr. Gene Willeke (co-authors) and Dr. Ernie Carlson. All but Dr. Willeke are members of the staff of the Corps Institute for Water Resources. Dr. Willeke was an IWR Visiting Scholar from Miami University (Ohio) during the first year. Mr. Zoltan Montvai oversaw the study from the Corps Policy and Planning Division at Headquarters. Mr. Kyle Schilling (IWR), Dr. Eugene Stakhiv (IWR), Charles Lancaster, J.D. (IWR Visiting Scholar) and Mr. William Johnson (from the Corps Hydrologic Engineering Center) provided continuing counsel and direction to the study team.

The names of the principal study contributors are so numerous that we created Appendix A to list them. We thank all those who helped.

I. Introduction

AUTHORITY FOR THIS STUDY

The impetus for the study was the Corps involvement in water management conflicts during the droughts throughout the country from 1986 to 1988 (and that continue in many places). This study is being conducted under the authority of and in partial response to Sections 707 and 729 of the Water Resources Development Act of 1986 (WRDA 86).

Section 707 ("Capital Investment Needs for Water Resources") authorizes the Assistant Secretary of the Army for Civil Works (ASA(CW)) to estimate long term capital investment needs for, among other things, municipal and industrial water supply. Section 707 specifically requires estimates of current levels of service and estimated future requirements; an identification of key policy issues; identification and analysis of economic and engineering assumptions; estimates for O&M costs; estimates of similar expenditures by State and local governments; estimates of demand, need, and service capacities of existing and planned investments, an analysis of the effects of delaying such investments, environmental, economic, and social benefits involved; and an analysis of different levels of cost sharing.

Section 729 ("Study of Water Resources Needs of River Basins and Regions") requires ASA(CW)), in coordination with the Secretary of the Interior and in consultation with other governmental agencies, to study "water resources needs of river basins and regions of the United States." This section specifically requires consultation with "State, interstate, and local government entities."

DEFINITIONS

Definitions of drought are usually framed by references to long periods of below normal precipitation. The meaning of the word "drought" in this report is *the condition of wide spread and negative economic, social, and environmental impacts because there is less water than expected.* That shortfall can come from a lack of precipitation and/or a deficiency of water in storage, a problem with the distribution systems, or inefficient use of water This broad definition was used so as not to exclude consideration of situations (such as the failure of an aqueduct supplying water to a city) that could cause impacts similar to drought caused by a lack of rain. In practice, legal authority for responses to drought is triggered when some agreed upon conditions which define drought have been met. The operational definition of "drought" must be limited and regionally specific.

Water management refers to the planned intervention in the hydrologic cycle in order to enhance water uses and reduce the water hazards . That intervention is considered good when the benefits of intervention exceed the costs. In practice, it may be very difficult to know with precision what the benefits or costs are. Water management measures include a broad spectrum of measures, ranging from regulation of development which affects water runoff, to water storage and regulation, flood damage reduction, water quality intervention, demand management, and cloud seeding. Water management during drought, from the title of this study, refers to intervention in the hydrologic cycle for the purpose of reducing the adverse impacts of drought, it refers to activities preceding a drought as well as operations during the drought.

Water supply planning is the study of measures to balance supply and demand in such a way as to meet specific goals, such as minimization of economic and environmental impacts. Water supply management is the timing of control of water. It includes activities designed to assure a specific quantity and quality of water.

Conservation, in general means to protect from loss or depletion; to preserve. Water conservation as used in this report refers to the careful use of supplies through demand reduction or more wise and efficient use (e.g., optimal scheduling of deliveries, or conjunctive use of reservoirs).

STUDY PERSPECTIVE AND SCOPE

This study addresses water management during drought at all levels, throughout the United States, is Federally funded, and is managed by the Corps of Engineers.

Drought impacts resources other than managed water resources. These impacts to other resources are very significant. Drought losses in dryland farming and forestry were much larger in 1988 than losses in industries which were served by managed water supplies. Impacts related to un-managed water - caused directly from a lack of rainfall - are considered in this report if there is a relationship to water management goals. Response institutions designed for water management are unlikely to function well without an effective and direct linkage to decision making parties and institutions concerned with drought impact mitigation. The institutions and perceptions of drought management are also relatively well-developed for impact mitigation compared to water management for drought because of the magnitude of such problems in the past. However, current demands are so similar to water availability that improved water management planning is now needed to complement and improve both processes through water management and drought mitigation. In the long term, there is also a linkage through the strategic question about the value of water to irrigate crops to supplement the production from dryland farming as compared to the value of that same water to meet non-agricultural needs.

STUDY METHODS AND PARTICIPATION

Water management during drought is not the province of any one level of government or any one profession. A deliberate effort has been, and will continue to be made, to include in this study all the groups and skills that actually contribute to the practice of water management during drought.

The plan of study was developed by a group of twenty water managers from the Corps of Engineers Divisions and Headquarters (representing planning, operations, and engineering functions), and four water managers from outside the Corps.

Senior planning, operations and engineering chiefs in the Corps Division offices responded to questionnaires designed to find the greatest regional concerns from a Corps perspective. A summary of their responses is included in this report beginning in Section III and Appendices E and F.

Three workshops, were sponsored by the National Study of Water Management During Drought, the Western States Water Council (WSWC), and the International Drought Information Center (IDIC). These workshops brought together state, municipal, university, and Federal drought experts to define and prioritize problems. The first workshop, held in Phoenix in January 1990, concentrated on Corps problems and established a link with the drought study efforts of the Bureau of Reclamation, the WSWC, and the IDIC. The second workshop, held in Houston in April and sponsored by the WSWC, concentrated on the concerns of the Western United States. The third workshop, co-sponsored by the National Study and the IDIC (among others), held in Denver in May 1990, was a broad-based workshop which added the perspectives of the media, Regional Climate Centers, other Federal agencies, meteorologists and hydrologists to previously-gathered perspectives.

In addition to the three workshops discussed above, members of the drought study team participated in the National Science Foundation Workshop (for hydrologic research needs related to drought), Washington, D.C., May 1990, and the Corps Legal Services/Judge Advocate General Water Law Symposium, Phoenix, Arizona, May 1990. The study team met with environmental organizations, interstate organizations, river basin groups, and professional societies.

Studies were contracted to the Corps Hydrologic Engineering Center, in Davis, California; Resources For the Future, and the Advisory Commission on Intergovernmental Relations, both in Washington, D.C.; and Planning and Management Consultants Limited, Carbondale, Illinois. Reports from each of those studies are available separately; the principal conclusions from those studies have been incorporated into this report. Those reports are listed in Table 1.

Table 1. Support Studies Prepared as Part of the National Study of Water Management During Drought.

Study	Author
A Preliminary Assessment of Corps Reservoirs, Their Purposes, and Susceptibility to Drought	Hydrologic Engineering Center, Corps of Engineers, Davis, CA
Water Management During Drought; Research Assessment	Planning and Management Consultants, Ltd., Carbondale, IL
Intergovernmental Coordination for Drought Related Water Resource Management	Advisory Council on Intergovernmental Relations, Washington, D.C.
Integrated Framework for a National Water Management Under Drought Study	Resources for the Future, Washington, D.C.

Assistant Secretary of the Army (Civil Works) Robert Page wrote the governors of the 50 states, and all other Federal agencies with drought-related responsibilities, and asked them to provide their perspectives on the study issues. That coordination continues to produce a broad picture of *needs*, other ongoing research and development, and some suggestions for solutions. A summary of the states' concerns is provided in Appendix D "State Concerns."

Table 2. Federal Agencies Invited to Participate in This Study

Department of the Interior The Bureau of Reclamation U.S. Fish and Wildlife Service Bureau of Indian Affairs U.S. Geological Survey Bureau of Land Management National Park Service	Department of Defense U.S. Army Corps of Engineers
Tennessee Valley Authority	Department of Transportation The U.S. Coast Guard The Maritime Administration The St. Lawrence Seaway Development Corporation
Environmental Protection Agency (Assistant Administrator for Water)	Small Business Administration
Department of Agriculture Soil Conservation Service Farmers Home Administration U.S. Forest Service Agricultural Stabilization and Conservation Service Federal Crops Insurance Corporation	Department of Energy Federal Energy Regulatory Commission
Department of Commerce National Ocean and Atmospheric Administration Economic Development Administration National Weather Service	Federal Emergency Management Agency
	Council on Environmental Quality
	Office of Science and Technology Policy
	Department of Housing and Urban Development
	International Joint Commission, US and Canada
	U.S. Section, International Boundary and Water Commission, US and Mexico.

OTHER RECENT STUDIES

Several reports have documented the recent drought impacts and our nation's response to those droughts. Among publications that provide a broad overview of the most recent droughts of the 1980's are the following:

- The Drought of 1988 (Final Report of the President's Interagency Drought Policy Committee[1]);
- The Compendium on Water Supply, Drought, and Conservation[2];
- Managing Public Water Supplies During Droughts: Experiences in the United States in 1986 and 1988[3];
- Drought Water Management[4]; and
- Drought and Natural Resources Management in the United States. Impacts and Implications of the 1987-1989 Drought[5].

WATER MANAGEMENT - PURPOSES AND USES

Water is managed for many purposes. The actual mix of uses varies widely depending upon the particular needs and opportunities in a given region. Some purposes require offstream use (withdrawn from the body of water and used elsewhere) while other purposes require instream use. Some purposes consume a large percentage of the water used while others are non-consumptive. Some purposes make large changes in the chemical and energy characteristics of the water used while others leave them unchanged. Some purposes conflict with each other while others are complementary. In times of normal precipitation, conflicts between uses are relatively easy to manage. During droughts, conflicts become intense and extremely difficult to manage. The purpose of water management during drought is to balance the competing demands of each purpose in order to meet human, economic, and ecological demands with as little conflict as possible. The major uses of water are described below. The possibility for conflicts between users during drought encompass all uses in various combinations.

OFFSTREAM USES. Most of the water withdrawn for these activities is subsequently returned to a source where it can be reused. Consumptive use is the portion that is withdrawn and not returned to a usable ground or surface water source. Consumption of water by use, in 1985, is shown in Figure 1. Offstream uses by the different categories are explained in the following paragraphs.

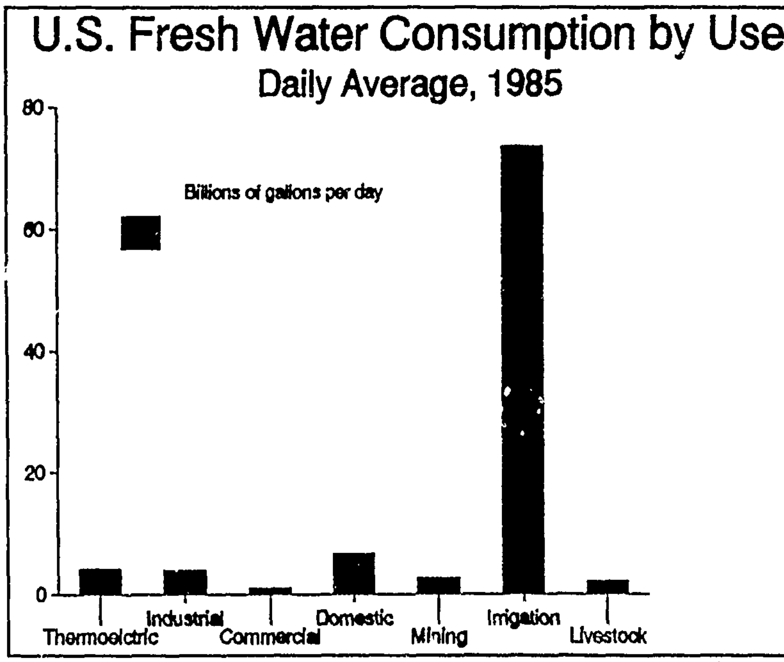

Figure 1. Daily Water Consumption in the U S. by use, 1985 (source: U.S. Geological Survey 1988).

Municipal and Industrial. This category of uses refers to water withdrawn by public and private water utilities and delivered for domestic, commercial, industrial, and thermo-electric power uses, as well as self-supplied water for these uses and for mining. Industrial quantities include water used for processing, washing and cooling. Mining consumption includes water used in the extraction of naturally occurring materials, including petroleum, dewatering, milling, and other preparations that are a part of mining activity. Thermoelectric power consumption includes water used for cooling in the production of electricity generated with fossil fuel, geothermal, or nuclear energy. Most of this water is returned to streams. Very little is consumed and it is usually returned to streams after treatment.

Agricultural. This is water withdrawn for irrigating crops and watering livestock. Irrigation withdrawals account for about one-third of all withdrawals. Unlike water withdrawn for municipal and industrial uses, much of the water withdrawn for irrigation is consumed It is returned to streams, sometimes with added and leached chemicals without treatment.

> *More than 80% of the water that is consumed in the United States is used for agriculture.*

More than 80% of the water that is *consumed* in the United States is used to irrigate crops and water livestock Irrigation consumption includes water artificially applied to farm and horticultural crops as well as water consumed in irrigating public and private golf courses. In recent years the amount of water used for irrigation has declined slightly, back to 1975 levels, during 1980 to 1985. Irrigation predominates in the West and the deep South, but is not as significant in the North Central and Northeastern states. California and

Idaho are by far the greatest users of irrigated water, ccounting for 37 percent of the national total.[6] Twelve percent of the farms in the 48 contiguous states are irrigated[7], but 29 percent (60.5 million acres) of farmland is irrigated[8], producing 30% of all farm sales.[9] Among crops with at least one-half of their acreages irrigated are sugar beets, berries, vegetables, irish potatoes, and orchards (which have approximately 70% irrigated acreage).[10]

Twelve percent of farms and 29% of farmland is irrigated, producing 30% of all farm sales

In areas such as in the Phoenix, Arizona area and between the Imperial Irrigation District and Metropolitan Water District users of Southern California, there is a market driven trend to convert irrigation water and facilities to municipal and industrial use.

Livestock watering statistics include water withdrawn for watering farm animals, including dairy and fish farming. Livestock *withdrawals* amount to only about one percent of total withdrawals.[11]

INSTREAM USES. Instream uses may or may not compete with offstream uses, depending on the timing and location of the withdrawal with respect to the instream use, as well as the quantity and quality of the water returned after offstream use.

Navigation. Inland navigation requires large amounts of water in order to operate. It uses natural streamflows, often modified by locks and dams to float barges. During low flows, some reservoirs are operated to supplement natural flows and maintain navigation depth. The U.S. has 25,000 miles of inland and intercostal waterways with over 200 locks and dams.[12] The Missouri and the Mississippi south of its confluence with the Missouri have no locks, but have extensive river training structures.

Great Lakes navigation facilities include a series of 16 locks and connecting channels.[13]

The system is efficient in moving bulk commodities (coal, grains, ore, petroleum) over long distar. . Grain and coal are particularly significant to the economy, and to the balance of trade with other natio.... Energy commodities (primarily oil and coal) make up about 55% of total waterway tonnage.[14]

Internal waterway traffic has grown from 291 million short tons in 1960 to 535 million short tons in 1985.[15]

Stored water on the Missouri River is currently used by the Corps of Engineers to maintain a schedule of discharges for navigation (and water supply, hydropower, fish and wildlife habitat, recreation and other uses) on the lower Missouri River. During low flow conditions such as occurred during the Drought of 1988, releases from Missouri River reservoirs benefit not only the Missouri River Project purposes, but also navigation on the Mississippi River. Navigation conditions in the lower Ohio and Mississippi Rivers are a consideration in negotiation with the Tennessee Valley Authority (TVA) regarding releases from Kentucky and Barkley reservoirs on the Tennessee and Cumberland Rivers, but the water is not stored specifically for navigation. The mainstem Mississippi River also benefits from reservoir releases that are made for water quality, hydropower, and fish and wildlife.

Hydroelectric power generation. Hydroelectric power generation utilizes the energy of falling water. Usually the water is stored in reservoirs and is released on demand. It makes no other changes in the water.

Instream withdrawals for hydropower has increased more than three-fold since 1950. However, there has been a decrease in water use between 1980 and 1985, possibly owing to better estimating techniques.[16] In 1986, hydropower produced about 12% of total U.S. electricity.

Private utilities, municipal agencies, cooperatives and Federal agencies produce hydropower in the U.S. In 1983, there were 1,550 hydropower plants in the U.S., about 90% of them non-Federal, most commonly owned by municipalities. However, federal plants have about 52% of the capacity to produce hydropower.[17] By 1983, almost half of the total potential hydropower capacity in the U.S. was already developed, according to the Federal Regulatory Commission (FERC).

Recreation. Water-based recreation takes place on lakes, reservoirs, and streams. The recreation experience usually deteriorates as reservoir levels decrease. In 1978 the Water Resources Council (WRC) estimated that one-quarter (20 million acres) of surface water in the lower 48 states was available for recreation. The rest was deemed inaccessible, polluted, or otherwise restricted from recreational use. WRC projected that 35 percent more area would be needed to meet acceptable standards of density for an expanding recreational demand. Current data indicate that demand for water related recreation at Federal facilities continues to grow at rates equalling or exceeding population increases.[18]

Fish and wildlife habitat. Fish and wildlife need water for habitat protection in streams and lakes. Minimum reservoir releases are often made to protect such habitat. This is water necessary to maintain the biophysical environment critical to fish and wildlife. Fish and wildlife benefits are generally thought of as benefits to public welfare not provided by private markets. The Second National Assessment by the U.S. Water Resources Council in 1978 assessed instream flow requirements in the United States.[19]

Wastewater Assimilation (treatment). About 31 billion gallons of water per day are returned to surface supplies in the United states after having been used for municipal or industrial purposes, and then treated. The parameters which describe the quality of water are all measured in concentrations, a ratio of substance to the volume of water. Hence, water quality standards can be met by removing pollutants or diluting the concentration of the pollutant by adding more water. In a drought, especially when conservation measures are instituted, the costs of treatment may increase because of the smaller amounts of water available for instream dilution, and reduction in velocity, which reduces aeration.

<u>OTHER CONSIDERATIONS.</u> In addition to the categories of withdrawal, consumption and instream uses listed above, reducing damages from floods and erosion are generally important concerns of water managers. Although the reduction in volume and flow of water during a drought tends to reduce these concerns, managers sometimes address special erosion and flooding influences on operations during drought.

For example, reservoir operation rules usually limit the amount of water than can be stored in anticipation of drought because of the need to keep reservoir space available to catch water that could otherwise flood communities downstream of the dam.

The problems of navigation on the Mississippi in 1988 were exacerbated by channel changes during low flow conditions Channel training and stabilization works generally provide a dependable navigation channel for most flow conditions. However, during the extreme drought, there were blockages due to reduced depth, and restricted widths impacted maneuverability of tows, rendering night navigation more hazardous.

Natural streams transport sediment scoured from stream beds and banks. When those streams are dammed and reservoirs are created, the suspended sediment settles out behind the dam, and the water released downstream is relatively free of sediment. This "clear" water will erode the downstream channel until its natural sediment carrying capacity is reached again. This "degrading" of the downstream channel may have serious implications during drought, since the lower stream bed, along with reduced flows, may leave water intake pipes high above water.

The best known linkage of soil erosion and drought, was the "dust bowl" wind erosion that occurred in the 1930's. Since most of the land that was affected then is still unirrigated, decisions about water management during drought have little effect on this problem.

Other considerations for water managers include adverse aesthetic impacts associated with both the drawdown at reservoirs and the dewatering of the normal flow channels during drought.

REGIONAL DROUGHTS IN THE U.S.

All regions of the country have experienced drought at some time; occasionally one or more regions may experience a drought at the same time.

When drought is severe and causes significant water shortages, people remember it by the years during which it occurred, for example, the California drought of 1976-1977. Figure 2 shows the more severe regional droughts since 1985 (source: Johnson, et al., Hydrologic Engineering Center, 1990).[20] The regions in Figure 2 represent Corps of Engineer Divisions. These droughts were designated as "principal regional droughts" by: (1) review of drought literature; (2) review of monthly Palmer Hydrological Drought Indices; and (3) discussion with water control managers. The droughts listed were notable for the duration (several years in most cases), magnitude, and geographic extent (region-wide as opposed to local or extralocal).

Several of the most recent droughts are not represented as "principal regional droughts." In some cases, they simply are remembered the most because of the recency, not only or necessarily because of the severity of the drought. In other cases, the drought may not have been region-wide. The Southeastern U.S. drought of 1985-1986, while receiving much publicity and causing substantial impacts, affected only part of the large South Atlantic region. Southern Florida, while in the midst of its worst drought in 200 years for most of the 1980's, is also not represented, because of the lack of its region-wide extent. Similarly, problems experienced along the lower Mississippi River because of low flows during 1988 are not presented as principal regional droughts, the low flows were caused by drought conditions in the upper portions of the Mississippi River basin and not by lack of precipitation within the region itself. Thus, the list of principal droughts represents only region-wide drought problems and droughts caused by hydrologic imbalances within the respective region.

Most regions have experienced severe drought conditions (principal droughts) within the last dozen or so years. Of noticeable exception, are the New England and North Atlantic regions, which last experienced severe drought during the early to mid 1960's. For much of the northeast, this drought is the "drought of record."

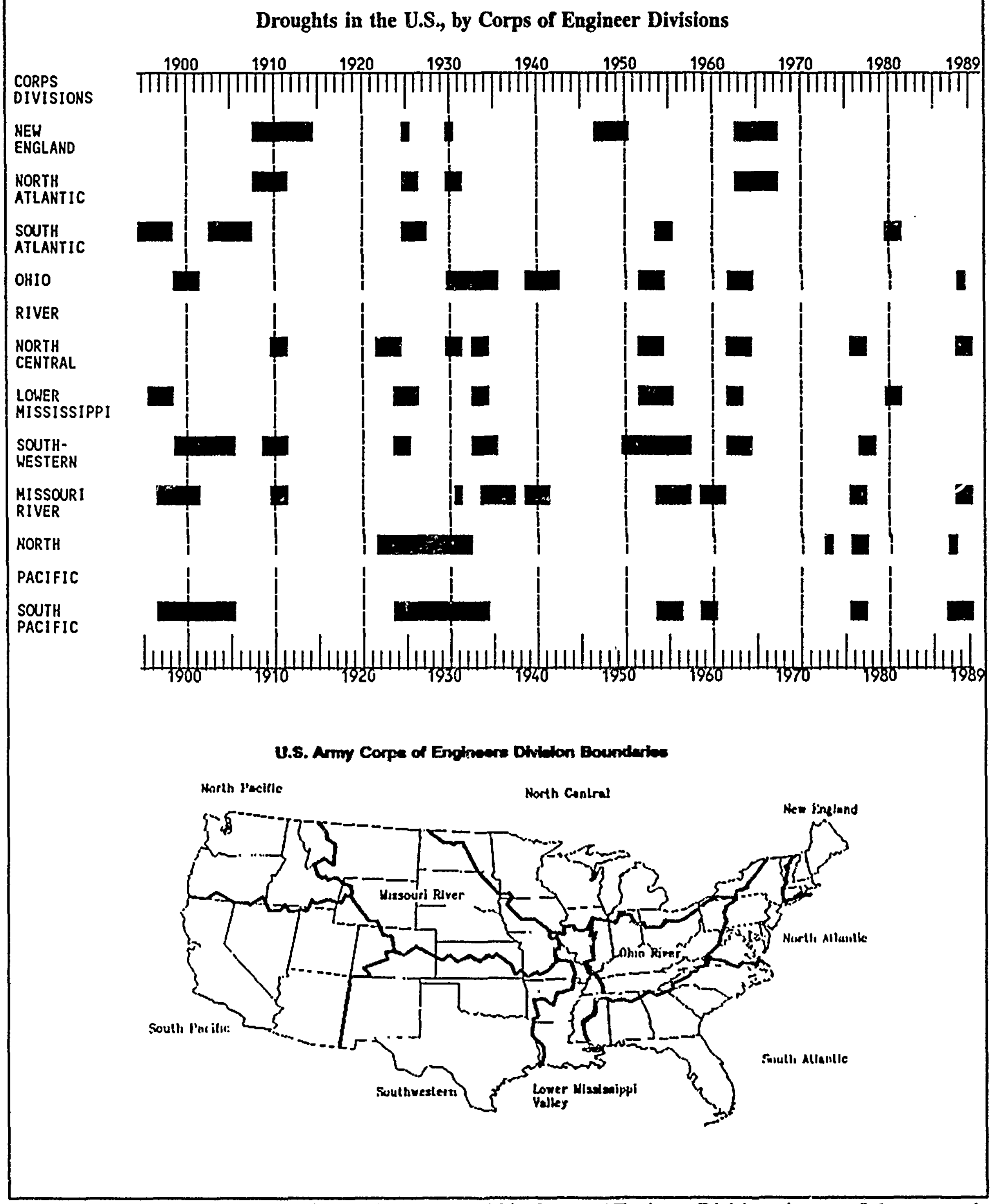

Figure 2. Principal Region wide Historical Droughts within Corps of Engineer Divisions (source. Johnson, et.al., HEC, 1990) Regions represent U.S. Army Corps of Engineer Divisions, illustrated in map at bottom.

II. How Is Water Managed Now?

Water management decisions involve rational analysis which requires the abstraction of reality - real water, real needs, real people - into models.

The doctrine of prior appropriation creates an abstract model of water *use* (not water itself) as a property right. That allows courts to analyze water use much as they do use of other real property. Engineers abstract properties of water - volume, flow, surface elevation - and use computer algorithms as crystal balls which show what would happen to a real river if a dam were constructed or the channel deepened.

The results suggested by such models must then be converted again into reality: to produce more hydropower according to the predictions of a *reservoir operational model*, to conserve water according to the prescriptions of a demand forecasting model, to build a dam according to the recommendations of a *planning process*, or to allocate water according to the decisions *in law*.

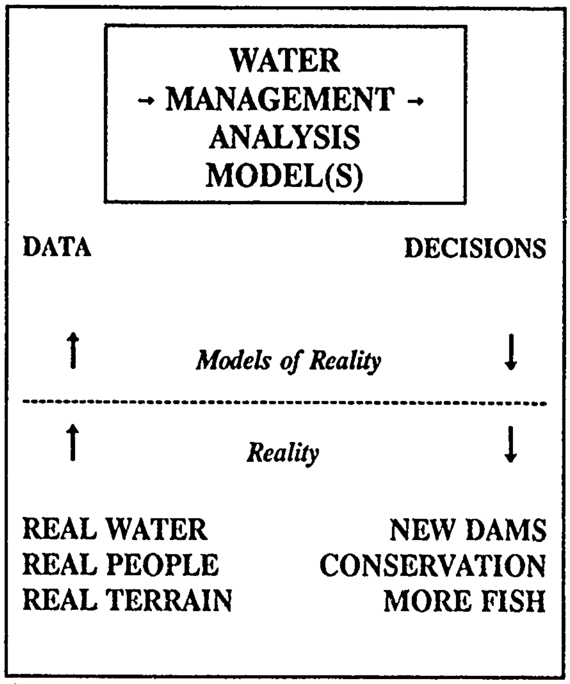

Figure 3. Water management decisions are made using models of reality - the law, fluid mechanics, politics - and the decisions reflect the perspective of the model(s) used.

Water management decisions are based on abstract models, processes and laws. They tend to be shaped according to the perspectives, biases and jargon of the particular model, and so become as identifiable with the model as with the reality being modeled.

A single type of model is rarely complex enough that it can be used alone to reach an acceptable decision, so the outputs from several models must often be developed and compared before a water management decision is made. (The engineer might say that velocity is proportional to the product of time and the acceleration due to gravity, the economist quotes the market price per acre-foot of water, while a pundit combines the models and says *water flows uphill to money*.) ***Water management is a product of the models used and the priorities of the decision process under which they are applied.***

Section II of the report discusses the basic concepts behind water management in this country, and describes the current realization - in laws, institutions, and practices - of those concepts.

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THE U.S. CONSTITUTION

The recognition by the states of the need for the consideration of the national good while still preserving the state's self interest is implicit in the limited delegation of power to the Federal government by the states in the Constitution. The U.S. Constitution, as amended and amendable by the people of the United States, is the set of rules, before all others, with which all water management in the country must correspond. Five Constitutional clauses define the boundaries of Federal involvement in water resources:

The commerce power. The constitution gives the federal government the power to regulate commerce with foreign nations, among the states, and with Indian tribes. This is the power with which the Corps is primarily involved. This power allows the government to regulate navigable waterways. It can be used to authorize dams for navigation and flood control at the same time providing for the generation and sale of power. This power provides a basis for construction of Bureau of Reclamation projects.

The proprietary power. This power allows the government to dispose of and make rules and regulations respecting the territory or property of the United States. This is the foundation of the reclamation program.

The war power. This is seldom used in water management but it was used to defend the construction of the Wilson Dam and power plant on the Tennessee River.

The treaty making power. Treaties have significance in the management of international waterways and with the Indian tribes.

The general welfare. This provides for the general welfare of the United States. The only limit to this power is that it must be exercised for the common good. This power has been used to justify some large scale water projects.

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TREATIES

State water law is subservient to treaties. The U.S Constitution gives the President power to enter into treaties with sovereign nations with the advice and consent of the Senate. Today, a doctrine of limited territorial sovereignty and equitable apportionment generally govern the resolution of international water disputes, most often by means of treaties.

The United States is party to several water treaties with Canada, including the 1909 Boundary Waters Treaty, the Lake of the Woods Treaty, the Saint Lawrence Treaty, and the Columbia River Treaty, and treaties with Mexico including the 1906 Convention (Irrigation) and the 1944 Mexican Water Treaty. The Columbia River Treaty with Canada provides for sharing of benefits for construction of reservoirs in Canada. Downstream power generation rights were equally divided, but Canada elected to sell back their half. These power generation rights revert to Canada, thirty years after construction of the first dam, in 1998 and will be completely returned by the year 2003.[21]

The 1909 Boundary Waters Treaty covers lakes, rivers, and connecting waterways, or portions thereof, along which passes the United States-Canada boundary. The Treaty includes western rivers that cross the boundary. The Treaty created the International Joint Commission as the agency through with questions arising along the frontier can be resolved.[22] The 1909 Boundary Waters Treaty also deals with diversions from the Great Lakes. Diversions through the Lake Michigan Diversion at Chicago is further limited by a 1967 Supreme Court decree; increases in flow out of Lake Michigan must be approved by the Courts or legislated by the U.S. Congress.[23] The Great Lakes Commission, created by legislation of the eight Great Lakes States in 1955, was authorized as an interstate compact commission in 1968, and deals with the resource and economic issues common to the region.

The Mexican Water Treaty of 1944 allocates to Mexico a guaranteed annual flow of Colorado River water, to be reduced in the event of a serious drought in the U.S. In addition, it outlines the aspects of international ownership of waters of the Rio Grande in its international reach and the development of the international reach of the Tijuana River. The treaty is administered by the International Boundary Waters Commission (IBWC), consisting of a U.S. Section and a Mexican Section. The IBWC has worked to deal with issues of water quality, especially salinity. Many water problems with Mexico remain unsettled such as dividing transboundary groundwater and disposal of hazardous wastes.[24]

Winters Doctrine. But perhaps the most significant treaties in water management are those between the Federal government and the Indian nations. Indian tribes have well-established rights to large, but for the most part unquantified, amounts of water. These rights are based on the concept that the establishment of Indian reservations meant not only that the *land* was reserved or confirmed but also that the right to sufficient water to fulfill the purposes of the reservation was reserved, although the early treaties with the Indian tribes seldom mentioned and never defined water rights. The U.S. Supreme Court first articulated this doctrine in Winters v United States in 1908 and reaffirmed it in 1963 in Arizona v. California. The reserved water right's priority is the date of reservation establishment. The right vests on that date and it cannot be lost by nonuse. The right is based on Federal law and is held in trust by the Federal government, it does not depend on state law or procedure for its existence.[25]

The U.S Supreme Court has held that water can be put to another use if quantities specified in right are not exceeded Thus Indian reserve rights can be changed from agriculture to recreational purposes such as along the Lower Colorado River. A major issue regarding Indian water rights is the question of whether tribes can sell or lease their settlement waters off reservation. It should be noted that most of the tribal water rights are "paper" water rather than "wet" water rights, that is a legal right to water that is not available for use. For many reservations, use on-reservation will require construction of diversion facilities.

These Indian claims to water are among the most contentious issues in the western United States. Some believe that exercising Indian water rights could severely disrupt the existing water use. Litigation has been the traditional mode of conflict, but in recent years there has been an increased emphasis on negotiation in this area.[26] As of June 1989, there were over 50 active general stream adjudications involving Indian water rights However six settlements have been made recently through negotiation and legislation, with the Department of Interior in the process of negotiating additional settlements.[27]

The Winters Doctrine applies primarily to prior appropriation doctrine areas. The courts have not decided how the concept of reserved water rights applies in a riparian jurisdiction.[28] Minnesota, for example, questions its applicability in riparian doctrine states.[29]

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LAW

In recognition of these powers many laws have been enacted regarding the management of the nation's waters which taken together help define the national interest. Laws created a federal role in water quality, water supply, navigation, irrigation, power, and fisheries. Some of these laws put the Federal government in the position of directing and some, assisting the states in carrying out the water related functions desired by the people.

Water rights under which Federal reclamation projects are planned, constructed, and operated, are issued by the states. In addition, contracts for operation, water deliveries, and repayment obligations are required by Federal law and are in compliance with state laws.[30] [31] [32] The history of Federal deference to state law in the construction and operation of water resources projects leads to presumption against Federal preemption. However, the presumption may not be a reliable guide to the future. Federal deference is decreasing as Federal regulation of water use for environmental purposes increases, for example, as per the Endangered Species Act of 1973.[33]

Federal laws concerning water management include: *interstate compacts*, which are agreements among states ratified by the U.S. Congress; *development acts*, i.e., periodic omnibus bills which authorize the construction or study of water resources projects, and *regulatory acts*, which require certain water management guidelines to be followed nationwide.

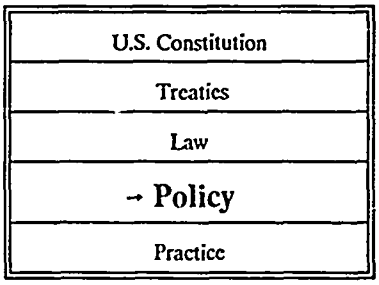
The *right to use water* is established in accordance with state laws and Indian treaties, and they differ significantly from place to place. Two basic doctrines and two common variations control the acquisition, use and transfer of water rights. Most water is be subject to federal regulation under the Interstate Commerce Clause of the U.S. Constitution, and water disputes between the states have been resolved by the Supreme Court in a few notable cases.[34]

West of the 100th meridian, in semi-arid and arid regions (where water reservoirs capable of storing years worth of rainfall were necessary for the development of cities and farming), the law of *prior appropriation* is used Under appropriation law, the right to use a specific quantity of water from a stream over time belongs to the party who first beneficially used it, and who is still using it. Hence a prior, or a senior right, is a right based on a beneficial use that began earlier than another. This system of law theoretically allocates water during droughts; junior users lose their rights as the total amount of water available decreases.

In the water rich states east of the 100th meridian, water allocation is governed by the *riparian* system of law. As water has become more scarce in relation to competing demands and the need to manage its use has increased, the common law of riparian rights has been modified by legislation. Some states have enacted permit programs to provide more certain water rights. The humid state permit programs have been enacted to: (1) collect accurate water use information, (2) allocate water by more definite criteria, and (3) assert a stronger state interest in water use and management.[35] The U.S. Supreme Court's holding (Sporhase v. Nebraska, 1982) that water is an article of interstate commerce has created an additional incentive for many humid states to increase the level of water management to defend instate allocation choices against possible constitutional challenges.[36]

A doctrine incorporating both riparian and prior appropriative aspects, known as a *hybrid* system has been adopted by the Pacific Coast states and the states that straddle the 100th meridian from Texas to North Dakota.

Many states have *permit* systems, including Arkansas, Connecticut, Delaware, Florida, Georgia, Indiana, Iowa, Kentucky, Maryland, Minnesota, New Jersey, New York, North Carolina, and Wisconsin.[37] [38] A basic purpose of eastern permit systems is to allocate water during short-term droughts.[39] Typically, eastern permit statutes require a permit from a state administrative agency to divert or impound water.[40] Indiana, New Jersey, and North Carolina require permits only for water use in "critical areas."[41] Florida, Kentucky, and Minnesota authorize establishment of emergency allocation rules during periods of drought.[42] In Florida, water management districts can develop different sets of rules for water allocation in different parts of the state.



Hierarchy of Water Management

POLICY

Federal. Over a period of 30 years, from the Great Depression to the early 1960's, the major federal water agencies hammered out a common set of policies and procedures for use in the formulation, evaluation, and review of federal and federally aided water resources projects. These policies and procedures were developed by interagency working groups that evolved into the Water Resources Council, they reflected and codified policies enacted piecemeal by Congress in a variety of laws, and they were confirmed by an interagency agreement approved by the president. The Water Resources Council was formalized as a regular part of the government in 1965, and remained in operation until 1982. It promoted multiple use river basin planning, federal interagency coordination, and intergovernmental consultation on water resources issues and projects.

The Nixon and Carter administrations both attempted, but failed to integrate national water policies further by reorganizing most of the far-flung water resources programs of the federal government into a major component of a Department of Natural Resources.

For the last two decades, there have been two broad-based policy development units in the Executive Office of the President with potential for helping to maintain and update government wide water resources policies and procedures: the Domestic Policy Council and the Council on Environmental Quality (CEQ). The former has had standing sub-councils covering broad areas of domestic policy in the past, but currently works through temporary "working groups" assigned to particular policy development tasks. Members of the working groups are assigned from the relevant cabinet departments and other federal agencies, as needed. CEQ is a three-member presidentially appointed, independent body with a small policy staff of its own. Traditionally its interests have been very wide ranging. In addition to its principal task of overseeing implementation of the National Environmental Policy Act, it has regularly reported on many national and international natural resources issues, including water resources.

The Corps of Engineers and the Bureau of Reclamation have multi-purpose water resources planning missions, although the priorities of the objectives are defined by the Federal interest, agency character, and the policies of the Administrative Branch of the Federal government. The Corps' traditional priorities have been navigation and flood control, with the central objective of increasing net National Economic Development (NED) Benefits within environmental constraints. The Bureau was created to develop the arid West with irrigation and water supply. Water control manuals are written to assure that the project is operated to meet Congressionally authorized purposes. Major changes in the way projects are operated require Congressional approval, but the agencies have fairly broad operational freedom within the original authorizations to maximize economic benefits and meet new uses for the water stored in these projects.

Still, there can be considerable definition as to the operation decision available. For example, the operational characteristics contained in the Federal authorizations, the state-issued water rights which define places and amounts for diversion and the type and locations of use, as well as the contracts entered into by the Bureau of Reclamation and the water users, all place boundaries on operation freedom.

Concern over Federal management of reservoir operations during major droughts led Congress in 1990, to consider legislation which would have required Congressional review and approval of changes in Federal reservoir operations which require only agency review now.. However, in the Water Resources Development Act of 1990 (Section 311), Congress only asked the Assistant Secretary of Army (Civil Works) to conduct a study of Corps of Engineer operations of reservoir projects.

An Environmental Protection Mission has been added to missions of the Corps of Engineers, as per the Water Resources Development Act of 1990. Although objectives of this mission are in the process of being clarified, it is worth noting that designation of fish and wildlife restoration could have significant impact on planning and operation of Corps projects as related to drought planning.

<u>Federal - State Partnership</u>. The Water Resources Development Act of 1986 authorized partnerships with the states and other non-Federal governments which permit planning for regional economic development and social well being as part of authorization studies for Federal projects. Maximizing net national economic development (NED) benefits is the principle objective of federal water resources project planning and is used as the basis for selecting the appropriate design alternative as well as the economically efficient project scale. An intricate set of Federal/non-federal cost-sharing and financing rules serve to apportion the costs of various project outputs (purposes) among the Federal and non-federal partners.

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PRACTICE

The practice of water management in the United States marries the abstractions of the constitution, law, and policy, as well as the abstractions of economists' and engineers' simulation models, with the reality of water and geography. The organizational marriage is between organization by river basins and by political units.

<u>Hydrologic organization</u>. The U.S. Water Resources Council recognized the need for standard geographic and hydrographic bases to maintain continuity in its assessments. To meet this need, the U.S. Water Resources Council, in 1970, in cooperation with the U.S. Geological Survey divided the United States into 21 major basins, each of which is further subdivided into many sub-basins.[41] Some of the basins extend into Mexico or Canada. The major surface water basins generally extend over several states, and any state may be part of a few basins. Many large underground aquifers underlie several communities, and sometimes several

states. Federal agencies have varying geographic bases for organization. The Corps of Engineers is organized, for the most part, according to river basins (see Figure 2). In addition, there are some river basin water management organizations.

Water management from a river basin perspective. To the extent that systematic water resources planning and coordination has been practiced, it has largely been on a river basin scale. The major federal water resources agencies began many years ago to use interagency river basin committees to share information about their activities in the nation's major watersheds. State officials often sat-in on these meetings, but they were not allowed to become committee members until the Water Resources Planning Act of 1965 provided a means for them to do so. The result was the formation of joint federal-state river basin planning commissions upon request of the states (the Title II commissions). In 1981 when President Reagan abolished them, these commissions covered about 40 percent of the nation.[44]

The Tennessee Valley Authority, is an independent federal corporation with development authority as well as planning authority for a specific river basin. Other regional management agencies are formed by interstate compact. They possess different degrees of authority and different forms of representation, depending upon the legislation establishing them, usually arrived at after years of negotiation. Each is tailor-made for its own situation, and each is consented to by Congress as well as the legislatures of the states involved.[45]

The Delaware and Susquehanna compacts both authorize regulatory, operating, and basin planning responsibilities. The Federal government is a compact member along with states in both. The Potomac compact also has federal government participation, but no legal authority. It does, however, manage a cooperative water supply agreement--along with the metropolitan Washington water utilities--guaranteeing the area a reliable supply of water well into the next century, even during a drought, using computer-based water management techniques. The Delaware River Basin Commission uses the same basic model as the Potomac Commission to manage its water in times of drought. These compacts and a few others, plus TVA, remain active.

Compacts also are able to cross international borders. The Great Lakes region provides an example. There, the International Joint Commission which includes Canada, provides framework studies for the whole international water region. Its work is supplemented by the work of the Great Lakes Commission, Council of Great Lakes Governors, Great Lakes Fishery Commission, and other related organizations.

Most river basins without either a Title II commission, TVA, or a compact commission were served by a federal interagency water resources committee. When the federal government withdrew from the Title II commissions in 1981, all but the Upper Mississippi, Great Lakes, and Ohio River Basin organizations gradually went out of business. The Federal government currently has no institutional advocate encouraging regional water management.[46]

While no formal national institutional advocate exists, the current Columbia River System Operation Review has gathered the considerable momentum of three major Federal agencies - the Corps of Engineers, the Bureau of Reclamation, and the Bonneville Power Administration - to address regional water management issues. Consideration is being given to expanding participation to include other Federal agencies as cooperating agencies under NEPA. The question of how drought fits into this system review will also be addressed .

Political organization. Within most governments - Federal, state, and local - there is a tendency to separate responsibilities for water supply, wastewater treatment, public health, and environmental protection. Thus, water resources coordination has as strong an intra-governmental relations component as it has an intergovernmental relations component.[47]

The following pages catalogue the division of responsibilities by the *purposes* for which water is managed. For each purpose, the *roles* of different *levels of government* are listed, and where applicable, specific information about how roles are coordinated *for that water management issue* is provided. Figure 4 depicts this matrix of roles, purposes and levels of government. But water management during drought may combine all these purposes, and so that synthesis is discussed under its own heading.

Roles and Types of Organizations

ROLES	Adjudicate	Legislate	Manage grants	Manage data	Research	Plan	Design	Construct	Operate	Maintain	Regulate	Respond in emergencies
Users and user groups												
Issues advocacy groups												
Utilities & other private org.												
Local government												
Regional bodies												
State government												
Federal government												

Figure 4. The complexity suggested by this matrix illustrates a real concern. how can many independent actors, each with individual criteria for success, act together to produce the most effective drought response.

Water Supply. Some research and regulatory roles can be generally classified under water supply, covering both municipal/industrial and agricultural water supply.

Data acquisition and forecasting. The U.S. Geological Survey's Water Resources Division maintains a continuous record of streamflows at about 7,000 sites nationally. Many of these gaging stations transmit data in real time via a geostationary satellite data collection system. These data provide the bulk of information concerning the occurrence of hydrologic drought. Water quality data is collected at many sites. The Survey also monitors aquifer water levels in thousands of observation wells, either continuously or periodically. In addition to providing current data to management agencies, the Survey also publishes a monthly report containing streamflow, water-quality, and ground-water level data for many index sites across the country. Division offices (at least one in each state) serve as local clearing houses for hydrologic data related to drought.[48]

In support of water control management activities for its some 600 reservoir projects, the Corps of Engineers operates and maintains 2,048 streamflow stations in addition to the 2,417 stations funded through the U.S. Geological Survey cooperative program. Automated data processing and analysis are carried out by various Corps offices. The Corps Hydrologic Engineering Center in Davis, California, is developing a Reservoir Database Network which links reservoir databases to databases on drought, precipitation, temperature, evaporation, streamflow, recreation, and population.[49]

The Soil Conservation Service has developed an automated system called SNOTEL to collect real-time hydrological data in high elevation areas. The SCS uses these data to make predictions on forthcoming water supplies from snowmelt (about 75% of the western U.S. surface runoff). Current year data are interactively available through computer modems. The Centralized Forecasting System (CFS) of the SCS, located in Portland, Oregon, is designed to give users rapid access to runoff predictions. Forecasts are available through the winter into early summer, for 10, 50, and 90 percent "exceedance probability" forecasts, monthly.[50]

Other automated hydrometeorological systems are run by the National Weather Service (NWS), the Bureau of Reclamation, the Corps, Bonneville Power Administration, the Forest Service, and the Bureau of Land Management. The NWS has a number of real-time hydrometeorological networks, and in the western U.S., cooperates with the SCS in the production of the seasonal forecasts of water supply from snowmelt, while providing similar forecasts in the Northeast. The NWS is proposing a Fiscal Year 1992 Initiative Water Resources Forecasting Services (WARFS) to take advantage of technological advances in data and modeling systems in order to provide water resources forecasts on a national basis. WARFS highlights better long-term forecasts of streamflow to support water management agencies such as the Corps of Engineers. The forecasts will be provided on a routine basis to support day-to-day operations of water control facilities, as well as in times of special need such as during droughts. The system which will incorporate probability and climate information into drought assessment and forecasting, is a combination of short-term and extended streamflow prediction system. A demonstration of WARFS has begun in the Colorado River Basin.[51]

Real-Time Water Control and Forecasting Methods

Water conservation research. The Corps of Engineers has developed a substantial body of applied research on water conservation strategies and techniques. The Corps focus on water conservation and supply research began in the late 1970's. Its interest in drought, however, had developed earlier. The Northeastern Water Supply Studies (NEWS) were initiated in 1965 in response to the droughts of the early to mid-1960's.[52] [53] [54] [55] These studies evaluated a wide array of alternatives and both supply and demand. In 1978, the Corps initiated efforts to integrate water conservation into its activities. The initial efforts of the program were a series of policy studies that surveyed available information on water conservation,[56] formulated water conservation principles,[57] and developed a procedures manual for evaluation of water conservation as part of municipal water supply.[58] Other efforts have included development of models to evaluate drought management measures and water conservation.[59] [60] [61]

Water marketing. Water rights are generally transferrable under the prior appropriation doctrine, although transfers may be difficult and in some places altogether minimal. In recent years, widespread attention has focused on water marketing, the voluntary sale and transfer of an appropriative right. Much of water marketing has involved sale and transfer of water rights from irrigated agriculture (often inefficient) to urban use. Some states have enacted statutes encouraging transfers of salvaged or conserved water.[62] [63] In 1988, in response to a 1987 Western Governors' Association report suggesting changes in state and federal law and policy to facilitate transfers,[64] the Department of Interior announced a policy, aimed at encouraging voluntary reallocation of water supplied by Bureau of Reclamation projects, conditioned on a number of factors,[65] such as concern about third party effects of transfers. Issues include impacts to instream uses such as fish & wildlife, injury to other appropriators, and effects on water quality. To the extent water rights are well-defined, they are easily transferred to higher uses during drought in the west. Ten western states have statutory or administrative authority to expedite water use permits and transfers under certain circumstances,[66] such as drought. Several states used such authority during the current western drought.[67]

Municipal and Industrial Water Supply. Federal involvement in the development of municipal and industrial water supply has been small and generally through large multi-purpose water projects. Its role is primarily in the development of primary drinking water standards, research to support those regulations, and financial support for small systems through the Farmers Home Administration (FmHA).[68]

The state role in municipal and industrial water supply has been more significant than the Federal. Forty-eight of the fifty states have accepted primary enforcement responsibility under the Safe Water Drinking Act, which requires that they do engineering plan review, compliance monitoring, periodic sanitary surveys, laboratory certification, and enforcement against violators. The Safe Drinking Water Act will have significant impacts on water utilities and state oversight programs, especially with small to medium size utilities.[69] The states also are involved in the allocation of water rights.

Agricultural Water Supply - Irrigation. Approximately three-quarters of the irrigation systems in the U.S. are under the control of local and private entities. At the Federal level, the Bureau of Reclamation is the principal participant. Its projects include 355 storage reservoirs, 16,047 miles of canals, 37,193 miles of laterals, and approximately 10 million acres of irrigated farmland.[70] The Corps of Engineers and the Soil Conservation Service also build and manage irrigation projects. According to a 1983 Congressional Budget Office Report, local sponsors pay about 11 percent of the cost of constructing irrigation dams. Hydroelectric power users tend to subsidize irrigators, whose repayment is based on ability to pay. In addition, until recently, irrigation projects have been economically evaluated using crop prices inflated by Federal price support subsidies.[71]

Some states, such as California, build and manage parts of the physical irrigation infrastructure. At the local level, distribution of irrigation water is usually provided through the structure of an irrigation district.[72]

Agricultural Drainage is a term used to describe the practice of installing systems to lower naturally high water tables to make land agriculturally productive. There are 421 million acres of cropland and hayland in the U.S. One hundred seven million acres are classified as "wet", of that land, about 80 million acres have drainage systems to make them productive. About 8% of this has been done with Federal money. It is unlikely that much of the remaining land will be drained because of the "Swampbuster" provisions of the Food Security Act of 1985 (Public Law 99-198) which denies certain USDA benefits to farmers who produce agricultural products on newly drained wetlands.

Recent Congressional legislation (Water Resources Development Act 1990, Section 308) calls for a long-term goal of increasing acreage of the nation's wetlands. The Corps of Engineers is to consult with EPA, the Fish and Wildlife Service and others. An action plan is now being developed. The effects of restoration and enhancement of wetlands upon agricultural acreage has not yet been studied.

Navigation. The Federal government has the primary governmental role in navigation. All inland or intercostal waterways except the New York State Barge Canal are Federal. The Corps of Engineers is responsible for operating and maintaining almost all waterway segments used for commercial navigation (except the Saint Lawrence Seaway). About one percent of Corps reservoir capacity is used exclusively for navigation, but navigation can also be maintained from a little over half of the storage labelled as "multiple purposes."[73] Inland waterways move over half a billion tons annually, and about 15 percent of all U.S. intercity freight.[74]

The U.S. Coast Guard maintains about 48,000 floating and fixed aids to navigation,; another 45,000 are privately maintained.[75]

Hydroelectric power generation. Federal hydroelectric power is usually developed as part of a multipurpose project. The Corps of Engineers (76 plants), the Bureau of Reclamation (52 plants), and TVA (31 plants) have built the major Federal facilities. Non-Federal facilities must be constructed under licenses issued by the Federal Energy Regulatory Commission. In 1983, there were 1,550 hydropower plants in the U.S., about 90% of them non-Federal, most commonly, municipalities.[76] Although non-Federal plants are much more numerous, Federal plants have about 52% of the national capacity to produce hydropower.

Six Federal agencies market power Federally generated power in the U.S.: TVA, the Bonneville Power Administration, Southwestern Power Administration, Southeastern Power Administration, Western Area Power Administration, and the Alaska Power Administration.[77]

The Electric Consumers Protection Act of 1986 (ECPA), among other things, established new criteria for FERC use in reviewing license applications, even at existing hydropower plants applying for a new license as the old one expires.

The new law requires FERC to give equal consideration to (1) energy conservation (2) fish and wildlife (mitigation and enhancement), (3) the protection of recreational opportunities, and (4) preservation of other aspects of environmental quality.[78] This law creates a new tension between Federal regulation and private property rights in appropriation states. The consequences of this law are especially important now as drought continues in many appropriation states, because of the 416 licenses which will expire by 2007, 169 will expire in 1993. The States have a role in reviewing hydropower license applications for consistency with water quality standards adopted under the Clean Water Act.

Recreation. During the period of the greatest Federal investments in water storage systems, the opportunities for water based recreation provided by this development could not be used to help justify construction. However, the Federal Water Project Recreation Act of 1965 stipulated that recreational benefits be considered project benefits, just as navigation and flood control benefits had been previously (with some limitations). Projections prepared by the President's Commission on Americans Outdoors[79], and data collected by the U.S. Forest Service[80] indicate that demand for water based recreation will exceed the growth rates of both population and land based recreation.

Water Quality. In general, local governments plan, finance, construct, operate, and maintain wastewater treatment facilities. State governments operate water quality management programs. This includes setting water quality standards, determining effluent limits, issuing National Pollution Discharge Elimination System permits (which are required of all municipalities and industries that discharge wastewater), and enforcing compliance with the permits. Some states also share in wastewater treatment facility capital costs. In the future, the States will operate revolving funds to finance wastewater plants.[81]

The Federal government enacts laws, promulgates regulations, and develops procedures and guidelines for managing water quality.

Currently, 15,400 municipal wastewater treatment facilities and 19,600 collection systems operate in the U.S. Serving approximately 70 percent of the population, 160,000 industries and an unknown number of commercial establishments, these facilities treat over 30 billion gallons of wastewater daily. When all requirements are met for treating municipal wastewater, the number of facilities will have grown to 17,000 plants and 22,900 collection systems.[82]

Fish and Wildlife Mitigation and Enhancement. Water is used to improve fish and wildlife habitat. Regulating levels in reservoirs or in-stream flows can affect water temperature, velocity, and quality, each of which can affect habitat quality.

Several Federal environmental laws influence the role of the Federal government during drought. The National Environmental Policy Act of 1969 requires that an Environmental Impact Statement (EIS) be prepared when a Federal agency recommends construction or modification of a water resources project that will have significant environmental impacts. The EIS must demonstrate how the recommendations meet the requirements of 15 separate Federal environmental laws and executive orders dealing with clean air and water, and the preservation and enhancement of human and non-human habitat. Planning for fish and wildlife objectives is a cooperative effort led by the project sponsoring agency with input from the U.S. Fish and Wildlife Service, the National Marine Fisheries Service, and from state fish and game agencies. Other state and Federal natural resource agencies may also be involved. The U.S. Fish and Wildlife Service coordinates the listing of threatened and endangered species. The Environmental Protection Agency must certify that NEPA has been followed before such recommendations can be implemented.

Section 10 of the River and Harbor Act of 1899 gave the Corps of Engineers the responsibility for regulating placement of fill into navigable waters (a term which has been defined by the courts to include almost all U.S. streams). Section 404 of the 1977 Clean Water Act requires a Corps permit for construction activities in wetlands. The practical result of these two laws is that a water project proposed by anyone must publicly demonstrate that the impacts of the project will be insignificant or, if there are significant impacts, must state what they are, what the extent is, and what mitigative measures are to be taken. This not only has the effect of allowing the public input on water projects, but of placing Corps district and division commanders in the role of judges in environmental disputes. Section 404 permits are subject to a veto by the Administrator of the EPA if it is determined that "the discharge of such materials... will have an unacceptable adverse effect on municipal water supplies, shellfish beds and fishery areas..."[83]

WATER MANAGEMENT DURING DROUGHT

There are many participants with many separate goals. Drought aggravates conflicts among jurisdictions and purposes.

There are many participants with many separate goals. Drought aggravates conflicts among jurisdictions and purposes.

Water management is exposed to the most severe or prolonged droughts. In general, the entity which operates a water storage system and/or the entity with reserved rights to the water decides how water will be allocated during drought. In appropriation states, the party with the most recently acquired right to water may have to suspend or limit diversions if flow is not adequate to meet authorized demands, although in a growing number of cases, water may be purchased from those with more senior rights. In riparian states, water supplied from reservoirs is allocated according to the values of the entity which owns and operates the reservoir, within the bounds of Federal and state law.

Interjurisdictional contracting is a fairly common means of sharing water sources, providing adequate water treatment capacities, and arranging interbasin transfers of water during drought.[84]

The Bureau of Reclamation, the Corps of Engineers, TVA and other Federal agencies as well as state and regional reservoir operators make water allocation decisions. In addition, the Corps, EPA, FERC, and the U.S. Fish and Wildlife Service play a significant role as enforcers of environmental requirements during drought.

During the 1988-1989 drought and its impacts on navigation, there was extensive coordination between the Corps, the U.S. Coast Guard, and the navigation industry. Among the task forces were: the River Industry Action Committee, the River Industry Executive Task Force, and the Lower Mississippi River Committee.[85]

Federal power marketing agencies sign contracts with private power marketers, guaranteeing them a certain "firm" or "minimum" supply of electricity. When hydropower generation falls during drought, electricity generated by other means must be purchased in its place.

The droughts of 1986 and 1988 highlighted the primary roles that state governments have during water shortage periods:

1. coordinate efforts through task forces;

2. provide data, technical assistance and emergency aid to local governments and farmers; and

3. regulate water use (in some cases).[86]

The stress created by drought on water management systems, both physical and institutional, has been addressed in the past by some general and some specific measures, many of which simply need to be better integrated into existing institutional structures to perform more effectively.

Many states responded to the droughts of the 1980's by passing legislation and organizing task forces and committees to coordinate drought water management efforts, including Georgia, Alabama, Florida, Virginia, Nevada, South Carolina, essentially all the Midwest states, Tennessee, Kentucky, North Carolina, Kansas, Iowa, and New Jersey. Florida's Water Resources Act of 1972 had already established five water management districts, and changed the basic system of state water law from riparian to administrative law, with strong regulatory power. The 1990's finds states continuing to respond. For example, Minnesota passed legislation in 1990 and formed a drought task force.[87] In addition, a few regional river basin agencies such as the

Savannah River Basin Drought Coordination Committee, the Interstate Commission on the Potomac River Basin, and the TVA also coordinated drought response efforts.[88] [89]

Drought contingency planning is a term applied to a broad range of preparations for drought to minimize negative impacts. Many agencies (Federal, state, and local) either have developed or are in the process of developing drought contingency plans. A few examples are discussed below.

The Bureau of Reclamation and other Federal agencies are currently working on water management during drought, both from a policy perspective and on specific conflicts. The Bureau of Reclamation has conducted a study (as authorized by the Reclamation States Droughts Assistance Act of 1988) on legislative and administrative recommendations for responding to droughts and related problems, and measures to mitigate the effects of drought. Their preliminary conclusions (their report is in preparation) stress the need for drought contingency plans, and the need for a standing drought response authorization for the Bureau of Reclamation.

Corps of Engineer actions during drought are guided, in part, by two Engineer Regulations. Corps Regulation ER 500-1-1 grants authority to field offices to construct wells and transport water to farmers, ranchers and political subdivisions within areas determined by the Chief of Engineers to be drought-distressed. Corps Regulation ER 1110-2-1941 requires preparation of drought contingency plans for its projects. The plans are being prepared on both an individual and a system-wide basis. All plans will be completed by the end of Fiscal Year 1992. Executive Order 12656 may also be applicable. It assigns responsibility for water control during a national security emergency to the Department of Defense (acting through the Secretary of the Army), and directs that plans be prepared for that eventuality. At present, the Corps is evaluating its responsibilities under that Executive Order.

There are a number of ongoing Corps studies concerned with water management during drought. The Corps of Engineers' Missouri River Division is conducting a 2 year study of user needs in the Missouri River Basin, in two phases, to determine if and how the Master Manual for operation of the Missouri River reservoirs should be modified. The Corps' South Atlantic Division is conducting a study of water supply reallocation at Lake Lanier, and has begun a reallocation study of the Appalachicola-Chattahoochee-Flint and Alabama-Coosa River Basins. It is facilitating coordination and water management planning among the states of Florida, Georgia and Alabama. The Corps' St. Paul District recently completed a Low Flow Review Report for the Mississippi River Headwaters Lakes in Minnesota.

The Great Lakes Commission has just completed a guidebook for Drought Planning, Management, and Water Level Changes in the Great Lakes, and is in the second phase of a study about the impacts of different Great Lakes levels.

The TVA is conducting a number of activities to alleviate drought impacts. They have prepared a draft Environmental Statement on the "Tennessee River and Reservoir System Operation and Planning Review" that considers drought concerns as well as other objectives. Also, TVA has a continuing effort under its Reservoir Resource Evaluation Program that examines opportunities to modify reservoir operations to alleviate adverse impacts.[90]

The Western States Water Council (WSWC) is updating its "Model Drought Plan" and is conducting a legal and institutional study for the Bureau of Reclamation on water management during drought.

The members of the Western Governors' Association (WGA) have responded to a questionnaire prepared by WSWC. WSWC has developed a state response capability and authority matrix, which shows the Governors' emergency powers and state water law.[91]

Dr. Donald Wilhite of the International Drought Information Center, University of Nebraska, has developed a "Ten-Step drought Contingency Plan" under a grant provided by the Climate Dynamics Program of the National Science Foundation. The project was initiated in 1987 with the seven states - Pennsylvania, South Carolina, Kentucky, Oklahoma, Montana, Colorado, and Oregon - participating in the development process.[92]

III. Impacts and Roadblocks

This section discusses historic and expected drought *impacts* (loss of production or capital, whether in the business world or the natural environment), and the *roadblocks* which stand in the way of reducing impacts during drought.

OVERVIEW: THE CHANGING IMPACTS OF DROUGHT

> *In the 1960's it was the Northeast's turn, and many urban water systems which managers felt were reliable either failed outright or came very close to failing.*

The nature of drought impacts has changed since the great droughts of the 1930's. The urban Northeast had developed water supply systems by the 1930's, and investment in such systems in other parts of the country during and after the Great Depression has helped to change the nature of drought impacts. The droughts of the mid-1950's, which affected the Southwest, the mid-continent, and the Southeast, caused less severe impacts: fewer farms failed, people did not go hungry, and urban centers continued to receive water supplies.

But in the 1960's a record drought settled into the Northeast, and many urban water systems which managers felt were reliable either failed outright or came very close to failing. Many water systems functioned only through extraordinary measures and unprecedented water conservation.[93]

Droughts of the 1970's and 1980's have continued to severely impact the nations. Direct losses of $10-115 billion in 1976-77 drought, and about $39 billion during the drought of 1987-89 have been reported. In addition to navigation and hydropower losses listed below, the 1987-89 losses including $15 billion in reduced crop output, $4 billion in expenses associated with the drought relief bill, $3 billion in insurance payments, $10 billion for increased food costs, $1 billion agricultural services losses, and $5 billion in forestry losses.[94]

Most of the 1988 losses were largely confined to non-irrigated farming and timber, areas where better water management would have had little short term effect. But the immediate impacts from the 1988 drought are less serious than the impacts we will almost certainly face in the future because we are best prepared for short droughts that follow long periods of plentiful rain and good crops.

One indicator (not proof) of the nation's overall concern with any problem is the amount of media attention it receives. Drought was one of the leading news stories in 1988. Was the amount of media attention a good indicator of the seriousness of the problem, compared to other vital issues of the day? In a recent poll of 20 environmental and science editors by Conserv90, (a national conference and exposition sponsored by four major engineering and water management professional societies), about two thirds of the writers felt that recent media coverage of water shortage was appropriate, only one thought there had been too much media attention. Ninety percent thought that Americans would continue to face major water shortage problems in the 1990's. When asked to rate the importance of water supply and conservation against all other major environmental issues on a scale of 1 to 5 ("1" signifying that water supply and conservation issues were the most important; "5", the least), 65% rated them "1" or "2".[95]

Many states when contacted by this study provided their perspectives on the most pressing problems. Their comments are included in the discussion of impacts (below), and are tabulated by state in Appendix D.

Corps of Engineer division representatives responding to a questionnaire listed some of their biggest roadblocks to reducing the impacts of drought. Their comments are included in the section entitled Roadblocks to Impact Reduction, and are listed in Appendix F.

IMPACTS OF DROUGHT

Impacts of drought can be broadly classified in terms of effects on activities or uses of water. Literature about drought impacts is substantial, especially for the most recent droughts. **Supply and demand** are never simple constants in regional or local water management during drought. The supply side is influenced by storage available, delivery systems, legal constraints, projected rainfall, and water quality. The demands are more than the sum of the demands for each water use; with each use there are questions of efficiency (can the same benefit be had with less water) and relative value (should water be allocated for this use or for some other?).

Water Supply - Municipal and Industrial. Public water supply is the fastest growing category of water uses.[96] Most states responding to Assistant Secretary Page's letter expressed some level of concern about public water supply systems. The states' response echoed an earlier report by the National Public Works Association that [although urban water supply systems as a whole are not a national problem, there are some significant water supply difficulties in the Northeast for large systems, and there is a national problem for small water systems, due to a lack of skill and capital, and the economics of small scale operation.[97]

Fifty percent of all water supply utilities in the country were adversely affected during the 1988 drought to the extent that they requested their customers to reduce consumption.[98] A June 1990 poll of U.S. mayors indicated that 27% of U.S. cities now have water shortages, and 41% anticipate shortages during the next five years. The shortages are expected to be caused by drought, growing population, water pollution, and leaks from distribution lines.[99]

The Safe Drinking Water Acts will have significant impacts on water utilities and state oversight programs, especially with small to medium size utilities. Contamination and depletion of groundwater supplies is a major problem. "Mining" of groundwater (withdrawing water faster than it is replenished) is occurring in a wide array of areas including, the Ogallala aquifer and aquifers serving the suburban areas of Chicago.[100]

Water Supply - Agricultural. Nearly half the states reported agricultural impacts from drought, but for most of these, the impacts were to dryland farming. Some non-irrigated areas could potentially be helped by irrigation projects. Massachusetts, Kentucky and Idaho reported conflicts in allocating water between agricultural and urban use. In California, that conflict is at the root of controversy about whether the state should reallocate water or build more supply storage.

Although harvests declined substantially in the United States because of the Drought of 1988, food prices rose very little because crop inventories were used to supplement supplies.[101] [102] And because the 1970's and the 1980's were the two wettest decades in the twentieth century[103] (despite significant droughts in each decade), water stored in reservoirs meant that irrigation in the West, Central, and Southeastern United states could continue areas where there were unusually prolonged rainfall deficits.

Navigation In 1988, navigation difficulties were reported by the Corps of Engineers all along the Mississippi, Ohio, and Missouri Rivers. Many other states have concerns about drought impacts on navigation, including states in the Northwest and the Southeast. Transportation losses during the 1988 drought totaled about $1 billion [104] These losses were mitigated to a certain extent by extraordinary measures taken by the Corps.

Hydroelectric Power There was significant loss of hydropower generation in the 1988 drought. It did lead to brownouts because of network interconnections and substitute sources of generation, such as coal and oil fired plants It should be noted however that power networks have finite power handling capability, and all other sources of electricity have higher marginal costs than hydropower. Among others, the states of Alabama, South Dakota, Oklahoma, Montana, California, Idaho, Oregon and Washington have expressed their concerns about their states vulnerability to hydropower losses. Energy production costs increased by about $200 million in 1988.[105] There are indirect impacts of loss of hydropower generation such as pollutants added to the environment from alternative sources of electricity.

Recreation. Recreation facilities at many reservoirs were affected by the 1988 drought, with beaches, boat ramps, and public and private docks the most affected. In some cases, facility closures simply resulted in the shift of some visits to other areas in 1988. Sport and commercial fish species were impacted. Many reaches of the Nation's large rivers, areas that routinely produce walleye, northern pike, and yellow perch, were dry in 1988.[106] Georgia, Alabama, Tennessee, California, Idaho, Oregon, Washington, Wisconsin, North Dakota, South Dakota, Oklahoma, and Colorado, among others noted concern about drought impacts upon recreation and tourism (see Appendix D). Additionally, the economic effect on the recreation industry because of misconceptions about drought conditions can be significant.[107]

Environmental. One report noted that environmental losses were significant, but hard to quantify: "... the most long lasting effects of the 1988 drought will occur in the environmental sector, not in the economic sector."[108] But, they go on to say: "Cumulative stress on wetlands, wildlife, forests, groundwater, and soils cannot be measured accurately nor even, in many cases, estimated with any credence."[109]

Timber harvest during the 1988 drought was reduced by 20% and aggregate effects of increased vulnerability to insects, and stress to young trees will produce "negative forestry effects for up to 20 years, regardless of whether another drought occurs in the intervening period.[110]

Effects of the 1988 drought were pronounced on intermittent streams, small streams, headwaters of larger systems, and small impoundments, where there is often limited to no reserves to safeguard against droughts. The drought also affected the northern prairie marshlands limiting the size of duck breeding populations and production.[111]

Among states reporting problems or potential problems in meeting fish and wildlife requirements are Vermont, Florida, Nebraska, Oklahoma, Utah, Arizona, and Idaho (see Appendix D).

Several Mid-Atlantic states and Texas, Louisiana, and California expressed fear about salt water contamination. Many more states have listed saline water intrusion as a problem in general in the National Water Summary, 1983.[112] Important drinking and irrigation supplies are at risk in many of these states.

Water quality is a major concern in the northern central states with some states unable to drink the water beneath them[113] A major water quality consideration during drought is the effect of significant increases in water travel time through reservoirs that normally have relatively high flows and short water retention times.[114] Under certain drought conditions, water quality in these reservoirs suffers from warmer temperatures, resulting in low dissolved oxygen concentrations and anoxic constituents, such as iron, manganese, and hydrogen sulfide. Some fish species and mussels can be adversely affected by this poor water quality, both within the reservoir and downstream.

Drought can have long-term beneficial effects on the environment and on fish and wildlife production. For example, when a reservoir interrupts the natural wet-and-dry cycle of a downstream native prairie wetland, then the value of the wetland vegetation as habitat declines. The solution often involves inducing a drought by allowing part of the bottom of the wetland to dry out on a routine multi-year episode that attempts to follow prevailing dry episodes.[115]

Wastewater Treatment Several states have reported that low flows during drought impacted their ability to dilute effluent from wastewater treatment plants (see Appendix D).

IMPACTS AND ALLOCATION: COMPETITION.

Most often, the impacts of drought to one group of water users or one purpose cannot be isolated. Typically water uses compete with one another for scarce water during a drought. The following situations typify these conflict situations:

The U.S. Forest Service and Colorado are involved in litigation concerning the Forest Service's claim that it should be allowed to regulate water flowing through Forest Service lands to assure long term safeguarding of the watershed. Forty eight local governments and water developers, led by the Colorado Attorney General, are fighting the claim, calling the assertion unlawful and excessive. The Colorado Attorney General has said that this may be the most significant water case ever tried in Colorado, with implications for all the Western states, because half the water in the West either originates or flows through Forest Service lands.[116]

In New Mexico, the U.S. Forest Service has made a claim for the right to minimum instream flows for purposes other than the original multi-use and sustained yield of its forests. The U.S. Supreme Court held in the United States v. New Mexico (1978) that there is not a general Federal reserved right for instream flows for recreation, wildlife and aesthetics in National Forests. The Service now argues in District Court that occasional bankfull flows are necessary to maintain the channel configuration necessary for the original purposes.[117]

The Federal Energy Regulatory Commission's licensing review procedures for hydroelectric plants, as mandated by the Electric Consumers Protection Act of 1986. The Act requires that the agency give equal consideration to energy conservation, fish and wildlife mitigation and enhancement, the protection of recreational opportunities, and preservation of other aspects of environmental quality. This new Federal regulatory power may conflict with existing state powers to allocate water under appropriation law.[118] More licenses will expire in 1993 than in the rest of the century, so the licensing procedures may be the focus of increasing contention and litigation in the near future.

Operating Rules. The operating rules for federal projects are defined by federal and state laws, by contracts, by engineering judgment and standards, and by custom. Departures from these established behaviors can be expected to result in controversy, especially if there is insufficient planning and coordination preceding changes in these operational rules.

Most Federal reservoir projects were planned, built, and operated to meet the desires of local interests 20-50 years ago. Since that time, the needs in the project areas have changed, partly because of economic and demographic change and partly because the projects themselves induced change. In many cases, our understanding of project effects on natural and economic resources has improved. New storage sites are limited and expensive to develop. Public or private entities alike have a great deal of trouble constructing a new reservoir to meet almost any need. Consequently, the value of projects will rise in the future.

In the 1988 drought, some of the most common conflicts over allocation of water were among recreation, municipal supply, power, and navigation uses. These uses are not always in conflict, as water released for municipal supply may also benefit hydroelectric power, navigation, and in-stream flow requirements. The Corps Missouri River Division is currently conducting a review of the operating procedures for the Corps reservoirs on the main stem of the Missouri River. Underlying issues include roles between upstream and downstream states over the use of water from the upstream reservoirs. In addition, there are unresolved conflicts over the construction of the Garrison Diversion, which would provide irrigation for upstream agriculture, the adequacy of Corps drought contingency planning methods and tools for estimating the consequences of operating decisions.

The Tennessee Valley Authority has a continuing effort (under its Reservoir Resource Reevaluation Program) to examine opportunities to modify reservoir operations to alleviate adverse impacts. Objectives include enhancing pool level management and downstream minimum flows, especially during low flows.[119]

ROADBLOCKS TO IMPACT REDUCTION

Many studies before this have identified the specific impacts of drought. Most of the "easy" problems have been solved. The remaining problems resist change for a variety of reasons, identified below.

COOPERATION. The wide diversity of water users and responsible parties, each with their own goals, water rights, and incentive structures, often makes consensus among them difficult--even impossible at times.[120]

> *The problems most often rated most serious by Corps divisions were the inability to quantify non-economic impacts, and the absence of a specific procedure to justify operational decisions on the basis of whatever impacts were measured.*

The organization of water management responsibilities (see Figure 4) is involved and somewhat rigid. The mismatch between political and hydrologic boundaries leads to confrontations because different levels of government naturally put the concerns of their constituency first. A 1983 Congressional Budget Office (CBO) report notes that: "States or local governments subsidize facilities that serve their own residents, but they do not always have incentives to make investments that also serve the best interests of the economy at large. The Federal government is in the best position to ensure that infrastructure investments simultaneously advance national goals of efficiency and fairness."

COORDINATION. The most common criticism, if not the most serious, of agencies' response to the 1988 drought, was the failure to coordinate agency responses. This was said despite agency interest in improving coordination and notwithstanding the fact that coordination efforts seem to have improved since the 1970's. When governments organize themselves internally, they frequently structure their departments and agencies to reflect major constituencies rather than crosscutting issues. Furthermore, these structures tend to get frozen in time. Logical when established, they often are resistent to changing with the times.[121] In other cases, there may be recognition of the need,but not allocation of resources.

The three major workshops held as part of this study each had different proportions of Corps of Engineers, other Federal, state, regional, and university representatives, but there was general agreement at each workshop that the country would benefit from better inter-agency and intra-agency coordination.

> *The three major workshops held as part of this study each had different proportions of Corps, other Federal, state, regional, and university representatives, but there was general agreement at each workshop that the country would benefit from better inter-agency and intra-agency coordination.*

There are a large number of Federal, international, regional, state, and local agencies with some power or responsibility concerning drought. One of the most striking findings in reviewing the present line-up of responsible parties is how few agencies have responsibility for both surface and ground waters, and how few have responsibility for both water quantity and water quality.[122]

Corps of Engineer representatives felt that there was insufficient agreement among agencies - Federal and non-Federal - about their respective roles. Issues are communication with each other, and decision making in the absence of a formal mechanism. There was also a strong feeling that the role of the Corps during drought had not been either sufficiently defined or communicated to those responsible for water management decisions.

Many within the Corps of Engineers said that involvement with others outside the Corps was a problem. They report:

- inadequate public affairs work, either because of lack of public affairs training of technical staff, understaffing in public affairs offices, or of the inability of public affairs officers to get the right messages to the right people at the right time.
- lack of information on what other agencies are doing;
- that government agencies did not concur in a common set of objectives and priorities;
- there was no forum in which the agencies can talk openly with each other;
- that there were so many units of government with whom coordination is desirable that the sheer magnitude of the task is daunting;
- inadequate communication and contact with local universities.

COMMUNICATION. In general, mechanisms for communication may or may not be coincident with mechanisms for decision making. During drought, communication is essential among many parties, including other federal agencies, state and local governments, private water companies, individual water users, and the media. Not all of these entities have decision making power regarding either allocation or operational policies. The parties involved are likely to vary from year to year, and it may be possible to establish only the basic organizational structure and procedures for communication.

Confounding all efforts at communication is (again) the complexity of the drought.

TECHNICAL TOOLS. The complaint rated most serious, most often, by senior Corps division representatives responding to the study questionnaire, was the lack of two types of techniques:

methods for estimating the non-economic impacts of water management decisions, and;

methods for combining measurements of impacts into a defensible decision.

Research on drought forecasting models was regarded by most participants of the three drought workshops as something not worth the commitment of substantial resources at the present time. Our ability to forecast the inception or continuance of drought is primitive, and is likely to remain so for some time. Since quantitative forecasts of more than a few days are so inaccurate, the other elements of forecasting, such as demand and reservoir conditions are amenable to improved forecasting. However, despite limited skill in forecasting precipitation, there are efforts to improve forecasting abilities. Furthermore, in spite of uncertainty about future meteorological conditions, information (e.g., snow cover, soil moisture, reservoir levels) about drought-affected areas is known, information which enables the estimation of probability distribution of future streamflow as compared to historical streamflow. Such probabilistic forecasts of streamflow, such as those generated using the NWS Extended Streamflow Prediction System can provide water managers with risk information.[123]

Some participants in the three workshops believe that geographic information systems should have a prominent role in drought planning and in the management of water during drought emergencies. This would be done, in large part, by displaying sets of relevant information either on maps or in tables and charts that are geographically consistent.

There is fairly widespread, and widely reported dissatisfaction with existing drought indicators and a consensus that no single indicator of drought would be sufficient given the many manifestations of drought. On the other hand, some researchers are beginning to say that it is more important to make sure that the drought indicators we have are heeded and applied well than to search for better ones.[124]

The Corps of Engineers has created tools which can estimate municipal and industrial water use with and without conservation measures (IWR-MAIN)[125], and California has developed WaterPlan, which estimates conservation program savings, there are many areas which have not used demand forecasting models. Simple methods of estimation tend to produce very misleading results.[126]

DATA INADEQUACIES. Data inadequacies discourage effective water management during drought. Potential improvements in use of data (and models) in water management were judged to be among the most useful improvements, according to a survey of water management scientists and officials, following the 1986 Southeastern Drought.[127] About one-half of those surveyed judged use of data and models to be the most useful potential improvement. *Improvements scoring higher in the survey were public awareness programs, water use restrictions, drought proofing, and drought councils.*

The inadequate geographic coverage of National Weather Service/ U.S. Geological Survey gages is a problem for site specific-management of drought in some areas. Water managers, as a result, often are unable to know about the drought severity and magnitude until the drought is over. More gages, along with better predictive methods, would allow water managers to more effectively defend necessary conservation measures. Since the density of U.S. Geological Survey daily-flow stream gages is not sufficient to provide the needed streamflow information during droughts, the U.S. Geological Survey makes base flow measurements at miscellaneous sites during drought so that the areal extent and severity of the drought, at least in terms of streamflow, can be evaluated. The U.S. Geological Survey and other agencies have developed regional techniques for estimating drought statistics at ungaged sites. These regional techniques need to be improved so that better predictive methods are available to water managers.[128]

Effective reservoir operation during drought is especially impacted by data inadequacy. Data inadequacies cited in the literature include low flow data and analyses, low flow stage-discharge relationships, outflow rating curves, hydro meteorological data, environmental data for wetlands, water quality, pollution sources, fish and wildlife populations, ground water data, and economic data.

In particular, low flow hydrology and data are not well developed. Grigg and Vlachos call for federal and state researchers to give more attention to low flow hydrology, particularly what happens to streams and aquifers in times of drought.[129] They point out that hydrology textbooks generally do not address the subject of low flow hydrology.

The most frequently cited basis for the development of drought contingency plans for water supply utilities is the protection against the worst drought of record. Decades ago, the use of the flood of record was common in the sizing of flood control measures, but statistical analysis of flooding records is now universally used to assure sufficient, but not overly costly measures are planned. But floods last for a few days at most, so a 100 year record will contain 100 annual events to be used in the frequency analysis. In addition, floods can be characterized relatively simply in terms of discharge and other parameters of the floodplain topography and economy. On the other hand, droughts can last for years, and so a 100 year record may contain only a handful of events, and droughts have varying combinations of magnitude and duration. As a result, the drought of record is a less useful indicator for planning than the flood of record. The process of designing or planning for drought is certainly more complicated than using a flood of record for flood design purposes. Efforts should be made to determine recurrence intervals of droughts of different durations when considering design applications.

There are numerous other needs for improved data to support water management decisions. For example, more information about decision-making by the shipping industry during drought for utilization of inland waterways, and information about how delays in materials reaching factories impact the shipping industry would be helpful in making reservoir operation decisions regarding navigation.[130] Also, improved capability for collecting real-time water quality data would be helpful in making water management decisions, such as the timing and volume of releases for instream flow augmentation.[131] Other types of information of use to reservoir water managers, but often incomplete or unavailable, include water supply and use, and hydropower generation.

Lack of relevant scientific and technical water resource information contributes to inadequate policies and inter-governmental conflict within drainage basins. In the Missouri River basin, often heard complaints include:[132]

- Water resources data systems are incompatible with one another, are obsolete and are unreliable;
- Data are not generally accessible to users, including decision makers, professional water managers, and the public;
- Many basin governments (especially the Native American tribes) do not have the resources or technical experience to develop the needed water resources data systems.

In a survey of Missouri River Basin users of water resources data,[133] one-third of the data users claimed that available water resources data do not meet their needs. Approximately one-quarter of data providers professed to be satisfied with the water resources data they were providing. Data most often cited as unavailable was water use data. Next was ground water, especially localized information. Without these needed data, most users simply do without, or synthesize, extrapolate, and estimate missing data. These users may wait for improved priorities, contract for additional data, redesign collection networks, or seek assistance from other agencies to fill data gaps. Data providers and users ranked the data problems, the most severe problems, in order of severity:

- Period of record;
- data not up-to-date;
- high cost;
- missing parameters;
- data access;
- timeliness of access;
- data base structure

Specific data problems identified include: water resources data on the alluvial aquifer system, biological baseline data unavailability or disorganization, insufficient hydrological data on smaller watersheds, need for better documentation of frequency and concentration of trace toxicants in the river and the human health implications; need for ground and surface water analyses for naturally occurring toxic elements; and various meteorological needs such as better weather data collection efforts in mountain areas with unique weather attributes.

Improved methods of calculating probable impacts was considered to be of importance in both making and justifying decisions on water management decisions. There was a general feeling that neither sufficient data bases nor adequate analytical models existed to do this now.

LACK OF STRATEGIC PLANNING AND REGULATION FOR THE FUTURE. Strategic water supply planning (planning which responds to the long term interests of a region with regard to the use of water, especially during droughts) is either non-existent or geared to needs which are already outmoded, in many regions.

In 1985, 37 states had not started drought planning efforts, even though many had experienced recurring droughts over the decades.[134] By 1990, 24 states were without plans.[135] About 50% of the nation's water supply utilities had drought contingency plans in place before 1988, and less than 30% had any kind of quantitative data to support decision making during droughts. Half of the utilities affected wrote plans during the drought in 1988. In many instances, when plans did exist, they were based on little analysis and unrealistic expectations about consumer responses.[136]

There was consensus in the workshops conducted for this study that better planning for drought would improve the ability of water management agencies such as the Corps to operate effectively during drought. Better planning should include making allocation decisions and doing the negotiations that can best be done under calmer circumstances than prevail during a drought emergency.

The Hydro-Illogical Cycle is the name that has been applied by Donald Wilhite, Director of the International Center for Drought Information, University of Nebraska, Lincoln, to the demonstrated tendency for government, industry and the public to forget about drought once rainfall is normal or the reservoirs are full again. This forgetfulness has real, understandable causes. Because the time between major droughts is often a decade or more, other water management concerns naturally tend to fill non-drought year agendas. The time between droughts is often long enough for substantial staff turnover and reorganization, budget priority changes, and flagging public pressure. Solutions have been designed to deal explicitly with the tendency to forget about droughts once over (see Section IV, *Water Supply for the Washington, D.C. Area*).

Drought Perception and Response in Federal Agencies. The government has monitored and reviewed its performance during drought and suggested that improvements are needed.[137] The general public often believes that federal agencies deal with their own needs first, and other things secondarily.

Both the public and professional staff tend to perceive drought as a rare occurrence. However, hydrologists and climatologists consider drought just an event at the low end of the hydrologic or climatological continuum; in the extreme, drought is an outlier.

In general, Corps personnel feel drought should be dealt with as part of a water control plan that includes the entire hydrologic continuum. There should be one system, one organization, and one set of people involved.

Because droughts are not every-year occurrences in any region of the country, and because geographic differences have a major impact on the way drought response is best handled, the elements of good drought contingency plans are not well understood. Corps field personnel believe good model plans for operations during drought would aid in operating facilities and in responding to local conditions. This is especially true for interagency coordination.

LEGAL IMPEDIMENTS. Frequently, surface and underground water rights are treated differently by the states, making it difficult to manage the two sources together. Surface waters tend to be allocated as portions of expected flows, while underground water tends to be allocated as a right in the land where it is extracted so long as it is beneficially used on that land. In some cases, underground water cannot be transported off the land, therefore, it could not be managed conjunctively with river water which obviously would flow off the land.[138]

State laws sometimes make it difficult to transfer water rights from one use to another, and almost impossible to transfer from one state to another, but this is changing, and there are now a number of precedents for such transfers.[139]

Appropriation States. The priority of a water right, the essential feature of the prior appropriation doctrine, provides a basis by which all interested parties know prior to a drought, how water resources will be allocated during a drought. Most of the appropriation states' renewable water resources are already appropriated and developed while demands for water are undergoing major changes. New consumptive demands, derived largely from urban growth and increasing "instream" uses of water suggest a need for reallocation of a portion of developed water supplies.

The appropriation doctrine formerly has discouraged conservation because of a "use-it-or-lose-it" philosophy. The right to additional use of water saved, such as by a more efficient means of irrigation, may not necessarily be claimed by the user saving that water.[140] California has enacted legislation that permits the user to claim the saved water.[141]

Indian claims to western water and use of the public trust doctrine represent potentially large claims that may upset appropriated rights. Water rights are transferrable under the prior appropriation doctrine, although transfers may be difficult, in some places altogether minimal. Inhibiting factors include restriction of no injury to other appropriators. In recent years, widespread attention has focused on water marketing, the voluntary sale and transfer of an appropriative right. Much of water marketing has involved sale and transfer of water rights from irrigated agriculture to urban use. Some states have enacted statutes encouraging transfers of salvaged or conserved water.[142] [143] In 1988, in response to a 1987 Western Governors' Association report suggesting changes in state and federal law and policy to facilitate transfers,[144] the Department of Interior announced a policy, aimed at encouraging voluntary reallocation of water supplied by Bureau of Reclamation projects, conditioned on a number of factors.[145] Other factors may tend to limit water transfers such as concern about third party effects of transfers. Issues include impacts to instream uses such as fish & wildlife, injury to other appropriators, and effects on water quality.

Riparian States. Riparian law does not provide for specified allocations during times of water scarcity. The common law of riparian rights used in the eastern states has been modified by legislation as water has been perceived as more scarce in relation to competing demands . Some states have enacted permit programs to provide more certain water rights (see Section 2, Law, How is Water Managed Now?).

Permitting for Inter-basin Transfers. Many states have found that transfers of water between basins can provide an effective supplemental water supply, and have acted to eliminate or reduce the effect of watershed limitation. However, large-scale trans-watershed diversions are becoming more difficult in both riparian and appropriative states because of the heightened appreciation of the environmental and social consequences of such diversions. Some states have adopted a permit requirement to modify the common law prohibition against trans watershed diversions and use a permit requirement to give the state the power to assess and condition such diversion.[146]

DECISION MAKING. Water management decisions are made complex by the large number of decision makers at several levels of government and the problems reported above in planning, engineering, economics, cooperation, coordination, and the law.

Each state has its own constitution, laws, and organizational system, and each local government has its own ordinances, policies, water management institutions, and physical facilities. Similarly, each federal agency has its own authority and bounds, its constituencies and history, and a set of facilities or functions it is charged with managing.

The importance of this complexity is that each entity with water management responsibility must make decisions about supply and demand policies in light of conditions determined in part or in whole by another group of decision makers. For the case of a river with Corps of Engineering multipurpose reservoirs, a municipality might decide what actions to take in the next 30 days after learning what the Corps projected operating policies were to be for the next 30 days. A barge line might make similar decisions based on the same data.

However, such a division of decision-making does not mean that all aspects of these decisions need be or should be completely independent. On the contrary, it would be appropriate for sharing of information and decision making models before formulating operating policies.

Allocation decisions are not limited to a single agency. There are many decision makers who have to decide how to allocate the resources that lie within their purview. A decision made by the Corps affects decisions made by a state or municipality, on the one hand, or a barge operator or marina owner, on the other.

While planning is considered to be an essential part of effectively coping with drought, it was also recognized that planning alone will be unable to eliminate all damages. Some losses cannot be prevented. Some decisions must be made that will benefit one user at the expense of another, and the best of plans must be well-executed to be effective and minimize net overall impacts.

IV. Alternatives

This section discusses innovative approaches to managing water during drought. The first sub-section describes some generic methods and partial solutions which are generally available as options to a region looking to reduce its vulnerability to drought. Many of these measures have been used somewhere, even if only in demonstration projects.

The second sub-section describes how these pieces have been combined in real situations. The examples given represent just a few of the many efforts which have been made to find the right recipe of measures for a particular region. These examples were chosen because they are good examples of different basic approaches.

The third sub-section discusses what might be done on a national level to improve water management during drought. Included are two prominent suggestions - a national drought policy, and unification of Federal water management - as well recommendations from other drought studies. The last sub-section "Evaluation of Alternative Strategies" contains the reasoning for the conclusions and recommendations from the first year of this study.

GENERIC MEASURES

DEMAND AND SUPPLY MANAGEMENT. **Demand reduction** seeks to decrease the amount of water used, either over the long-term or during a short-term emergency. The usual options include: voluntary conservation; mandated conservation and bans on various uses, leak reduction, reuse of water; metering; pricing mechanisms; technological applications such as shower flow constrictors, ultra low-flow toilets, timers that shut off water automatically, etc.; and lifestyle modifications, such as changing from grassed to desert lawns.

Supply enhancement seeks to increase the amount of water available in a system. The usual options are to: increase storage (for either raw or finished water); increase transmission or intake facility capacity; increase treatment capacity; purchase or borrow water using system interconnections, activate standby or drill new wells; and reuse water.

The options of increasing storage, activating standby wells, and drilling new wells are easily understood and have been among the most common supply enhancement strategies. Similarly, purchasing or borrowing water are well-established practices throughout the country, especially in metropolitan areas.

One measure often promoted in the western United States is cloud-seeding, which seeks to augment water supplies by causing increased snowfall and thus more runoff. Many agencies (local to state) have implemented cloud seeding operations. The Bureau of Reclamation has a long-term recognition of and interest in cloud seeding research and technology transfer. However, the water management community and atmospheric research community are not all in agreement as to its efficacy.

The options of increasing transmission and treatment capacity are less obvious. In some cases, there is ample storage in reservoirs or water intakes, but there is insufficient capacity in either the intake structures or transmission lines to get water from the reservoir to the point of use. For example, transmission lines may be too small or have inadequate booster pump capacity. Intake structures may be located too high in a reservoir or stream to reach water levels during drought conditions.

Treatment capacity may be adequate for normal conditions. However, during drought periods with large reservoir drawdown, there may be taste and odor problems due to vegetative growth, especially algal growth, that can not be handled by the treatment facilities of water suppliers.

Water reuse may become one of the more important supply enhancement measures. It is used to some extent in most drought situations, rural or urban. Water reuse may occur at the level of the individual user (household, business, or industry) or it may be aided by the water supplier. Individual household users do such things as save water from dish or clothes washing for watering plants or even flushing toilets. Businesses may use "gray water" for washing floors, cooling, or for landscaping. Water suppliers occasionally assist individual users by making treated sewage available at little or no cost for such uses as landscaping.

REALLOCATION. Reallocation measures involve reassigning use of water from some current use to another use. This may be done through:

- directives of an agency director, such as a Corps of Engineers District Commander, if the reallocation is small;

- legislation (as in the case of federal reservoirs where certain uses were stipulated in the original authorizing legislation);

- litigation; or

- financial mechanisms such as sale (including barters and swaps), rental or leasing arrangements.

In addition to these methods, it is also possible to revise the operating rules for a reservoir or system in such a way as to increase the amount of water available for particular purposes.

The basic logic for reallocation is that conditions or increased knowledge have changed sufficiently to merit modification of past decisions. This typically pertains to the uses of a capital investment, such as a storage reservoir or transmission line.

Water storage and transmission structures have long life spans, which typically far exceed the economic life of the uses originally intended for the facility. New uses often have a higher economic and social value than existing uses. These long-lived facilities effectively tie up the water resource in a way that precludes development by other parties for beneficial use.

The Corps of Engineers Hydrologic Engineering Center identified eight general opportunities for reallocation of storage based on review of 16 current Corps reallocation reports. The eight general categories are shown in Table 3.[147] Other possibilities could be created based on the analysis of specific reservoirs.

Another approach to reallocation of storage is that of reassessing the operating rules for a reservoir in light of a longer hydrologic record, and of changing demands on the system. Reservoir operating rules are generally established prior to construction and tend to remain constant thereafter.[148] Systems techniques offer "opportunities to increase benefits of water resources projects if projects can be operated jointly as a system. Whenever two or more sources of water can be operated to meet a common goal or demand, the hydrologic reliability of the supply can be increased."[149]

There is a gap between research that has been accomplished in developing methods for analyzing reservoir reliability and optimizing release policies and practice (followed in the actual planning, design, and operation of reservoir projects). As the risk of failing to meet demands increases and reservoir operation decisions become more difficult, the usefulness of modeling techniques from the disciplines of resource

Table 3. Opportunities for Reallocation of Storage in Corps of Engineers Reservoirs.

CASE	DESCRIPTION	EXAMPLES
Use of water supply storage not under contract	Reservoir has storage for water supply, but contracts not signed	Sam Rayburn Reservoir, TX
Temporary use of storage allocated for future conservation purposes and sediment	Sediment space sometimes used as temporary source of water supply	
Change in conservation demand or purpose	Original project purposes may no longer be required or may be available or space can be used for higher ranked purpose	Denison Dam, TX, OK. Reservoirs in Kansas being studied under Kansas MOU
Seasonal use of flood control space during dry season	Probability of flooding during dry season is low in some regions of country. Conservation water can be stored in flood control space	Howard A. Hanson Dam, WA
Reallocation of flood control space	Small reallocations; change in downstream floodplain; reservoirs designed to maximum site capacity	Chatfield Res., CA
Modification of reservoir water control plan and method of regulation	No change in storage; opportunities created by change in delivery	John H. Kerr and Philpott Res.; W. Kerr Scott Res.
Raise existing dam	Increase total storage capacity	F.E. Walters Res.
System regulation of Corps and non-Corps reservoirs	Shift demand satisfaction from one reservoir to another	Kansas MOU; Smith Res.

Note: There are 23 Corps projects with 945,000 acre-feet of municipal and industrial storage not under contract. There is substantially more storage for other purposes not under contract, for example, in the Willamette Basin, Oregon.

Source: William Johnson, Opportunities for Reservoir Reallocation, 1988.

systems analysis and stochastic hydrology increases. Consequently, systems analysis and hydrologic modeling techniques should play an even greater role in reservoir operation in the future.[150]

One approach is the use of the space rule method, a way of increasing water yield by taking water out of the storage most likely to refill first. It attempts to keep the proportion of the free volume in the conservation pool to the expected inflow equal for all of the reservoirs in a system. In practice, minimum releases are often made from all reservoirs first, and additional releases are apportioned by the space rule.[151] It has been suggested that operating rules for water supply be developed on a system-wide basis as they are for flood control.[152]

Consolidation of storage is another way of increasing water yield by decreasing losses due to evaporation, seepage and in-stream losses. This is done by minimizing the surface-to-volume ratio of a reservoir system and storing as much water supply as possible nearest the users. Consolidation of storage is a method where conservation storage in the reservoir nearest the water supply users is maximized by releases from upstream reservoirs.[153]

INSTITUTIONAL AND MANAGEMENT ISSUES. The ability of water managers to use the available options for supply or demand management depends upon the existence of suitable institutional arrangements and conditions, and agreement by the pertinent decision makers on priorities and the appropriateness of the proposed options. Institutional arrangements and conditions include constraining and authorizing laws, mechanisms for communication among water managers and decision makers; and mechanisms for planning and coordination, and mechanisms for making both long-term and short-term decisions about water management.

Planning. There are two basic types of planning for drought: strategic planning and response planning. Strategic planning is meant to address the question: "how does the region want to be positioned for future droughts". Response planning accepts more things as given (e.g., current demand, environmental values, storage facilities, distribution systems) and attempts to design the best response within those constraints.

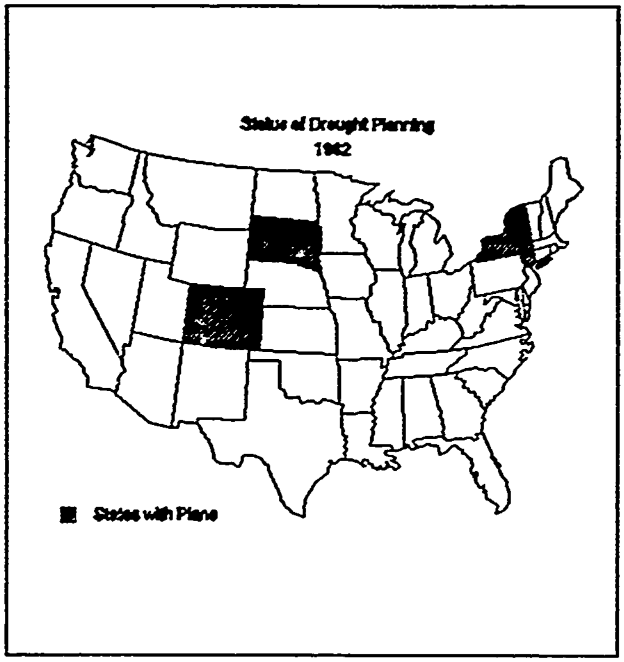
Examples of strategic drought planning in the United States are described in the Sub-section "Alternative Approaches Which Have Been Implemented." Drought response planning (sometimes called drought contingency planning) has been recognized as an efficient and effective way to reduce the impacts of drought. Figure 5 shows the dramatic increase in the number of states have planned for drought.[154] [155]

Coordination. The lack of suitable mechanisms for coordination of strategic planning *or* drought response efforts repeatedly emerges as being among the most important elements in dealing with drought.

On a national level, there have been many interagency coordination and planning bodies, including the Interagency Committee on Water Resources, a number of regional commissions, the Water Resources Council. For a variety of reasons, these coordinating mechanisms are gone, but the need for such mechanisms is as strong as it has always been, especially during drought.

California and the metropolitan Washington D.C. area have benefitted from coordinated strategic planning. The state of California has benefitted from an efficient working relationship among Federal, state, and regional water planners to assure enormous storage capacity for irrigation and populated arid regions. The Washington metropolitan area was forced to develop a collaborative problem solving network of federal, state, and regional water utility managers to assure that water needs would be met through conjunctive operation of existing reservoirs with just enough additional storage capacity to meet remaining uncertainty despite the more efficient management.

Communication. Communication between agencies and decision makers, and between agencies and the public have all been troublesome areas. Areas which have suffered with drought longer have developed better ways of communicating. The method most often recommended for better interagency communication is an ongoing awareness program: knowing the programs and people of other agencies *before* the drought. There is a body of research on how the public reacts to drought news and drought programs, and this has been used successfully by the Metropolitan Water District in California to improve public response in times of drought. Past reallocation studies by the Corps of Engineers have also highlighted the importance of developing simple information that can be distributed to the public via newsletters, workshops, and the media. Communication with the public is more successful when a public involvement specialist has an active role in rewording and presenting technical forecasts.



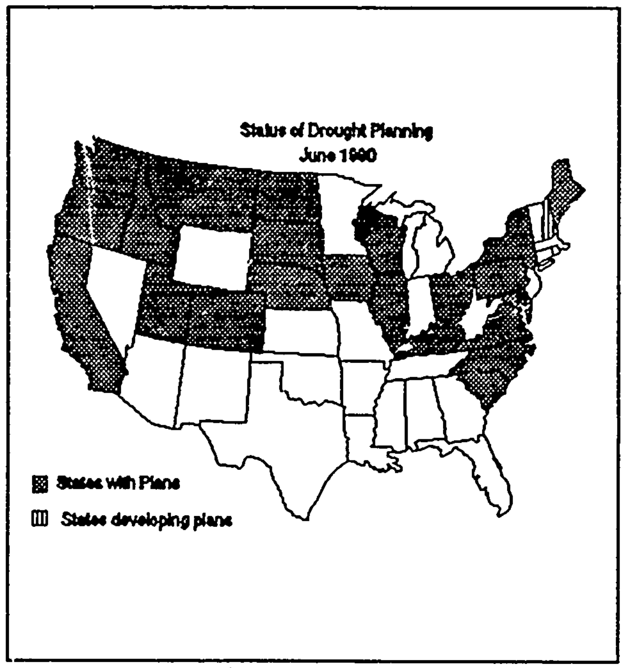


Figure 5. States with Drought Plans, Comparison of 1982 and 1990, from Water Management During Drought: Research Assessment, 1991 (and Wilhite 1990)

Organizational Changes. In the last several decades, many approaches to introducing greater cooperation and coordination into American government have been tried, with varying degrees of success. These may be viewed as catalysts, introduced to make the system behave differently without really changing the system itself. These catalysts are of two types: mediating *organizations* and mediating *processes*.

> Mediating *organizations* within the system provide advocates for cooperation and coordination - facilitators to remind and cajole, to provide information and analysis, to ask "what if," and to jawbone, but not to command.
>
> Mediating *processes* notify independent actors and affected interests of impending events, invite review and comment, and open the possibility of inter- and intra-governmental accommodations of diverse views.[156]

Negotiation. More than ever before, engineers find themselves in positions where unilateral technical decisions cannot be implemented.[157] The study of negotiation processes in recent years has improved the collective knowledge of negotiation techniques, including the circumstances under which negotiation is likely to produce results. Alternative dispute resolution, in particular, can be a worthwhile alternative to litigation, replacing the narrow conceptual model of case law with a broader concept which can incorporate equity, risk, expert judgement, and consensus tradeoffs. Negotiation techniques have produced solutions which have been generally applauded in a number of conflicts, including water supply from the Potomac River for the Washington D.C. metropolitan area. There is a discussion of the Potomac River case study on page 45.

Lt. General Henry J. Hatch, the Chief of Engineers established an official Corps of Engineers' policy to resolve disputes at the first appropriate management level through negotiation, and where appropriate, Alternative Dispute Resolution techniques.[158]

ALTERNATIVE APPROACHES WHICH HAVE BEEN IMPLEMENTED

There are many examples which show the need and resolve for substantial change in water management approaches, whether specifically oriented to drought conditions or not. These cases illustrate a variety of approaches by states, regions, and basins.

ARIZONA. Groundwater overdraft caused the legislature to pass one of the most significant groundwater management acts ever enacted. It requires a balance between withdrawals and recharge by the year 2025. Current demand is over 6 million acre-feet versus an average of just 4 million acre-feet of sustainable surface and groundwater supply.[159]

Arizona won a national public service award for this effort, but the ultimate success of the act will not be known for several years. Some of its toughest provisions are to be phased-in over a period of time.[160]

FLORIDA. Florida is divided into water management districts. The delicate environment close to sea level, flat, dependent on groundwater, and subject to seawater intrusion, has come under very heavy development pressures that threaten to overrun the sustainable supply of water and ruin the ecology. This situation has pushed the water management districts to become exceedingly careful and innovative stewards of their water supplies. The South Florida Water Management District appears to be the furthest advanced of the districts.[161]

CALIFORNIA. California has over 1300 reservoirs, and 400 ground water basins. The combined reservoir storage within or adjacent to California is about 43 million acre-feet.[162] About 143 million acre-feet of groundwater is usable.[163] Annual use is about 27 million acre-feet for agriculture, and 5.6 million acre-feet for all other uses.[164] With full reservoirs, California theoretically has five years water supply, an amount that seems more than sufficient based on historical rainfall records. Tree ring records indicate that the north part of the state had not suffered three consecutive dry years since the 1500's.[165] But in fall 1990, many parts of the state were entering their *fifth* consecutive year of drought, and concerns about the balance between demand and supply intensified.

In southern California, the Metropolitan Water District and many other cooperating organizations have created an ingenious system of imported water, local catchments, aquifer recharges, interbasin water transfers, seawater intrusion barriers, and reclaimed waters to meet the needs of a rapidly growing urban area in a very arid climate. This network allows mixing of water from alternative sources to produce a maximum of water with acceptable quality for specific purposes. Now, the District is eyeing the potential of reclaiming seawater.[166] The state of California created a Drought Center as an information clearinghouse on drought conditions, impacts, and response actions. The center prepares publications, organizes conferences, surveys water districts on the status of water supply, and assists water districts with shortage emergencies. *Similar ad hoc drought organizations were used in Illinois, Minnesota, and North Carolina.*[167]

HARRY S. TRUMAN DAM The Truman reservoir is the largest flood control lake in Missouri, with a storage capacity of over 5 million acre-feet.

A dispute not related directly to droughts arose between the Southwestern Power Administration, a Federal power marketing agency, and the state of Missouri. In order to meet peak power needs, water is released from the reservoir through turbines, but is pumped back into the reservoir when demands for power are off peak. It is economically efficient because the power supplied by the release can be sold at a higher price than the power needed to pump the water back into the reservoir.

When the pumpback was tested in 1982, it resulted in the loss of an estimated 2,000 pounds of fish which were drawn into the pumps and killed. The fight was joined by Congressional delegations of Missouri and the adjoining states because of concerns over environmental and electrical rate issues, and disagreements over the right of one state to take actions which would impose unacceptable financial impacts on the citizens of other states. Several attempts were made to settle the dispute through unassisted negotiations and a public involvement process, but to no avail. By 1988, the parties were deadlocked.

The Corps of Engineers hired an alternative dispute resolution consultant. The consultant reduced the number of parties involved in the negotiations to four (the state of Missouri Department of Natural Resources and Conservation, the Southwestern Power Administration, the Associated Electric Cooperatives, Inc., and the Corps). Lead negotiators were designated and given the authority to settle, and an opportunity to build trust and establish a positive working relationship was provided through the use of informal social time before negotiations. The consultant provided a structure for the parties to informally identify and discuss key issues to be addressed, and helped develop "single-text" negotiating documents which led to a decision on the number of units to be used for power generation and the procedure to be used to test the pumpback feature. The final agreement was approved by the Assistant Secretary of the Army on March 8, 1990. While the Truman case was not drought centered, the approach demonstrated could be applied to low flow management.

THE TENNESSEE VALLEY AUTHORITY. The TVA represents an example of comprehensive reservoir management of an entire river basin. During the harsh drought years of 1986 and 1988, TVA took a proactive approach to warning local, State, and Federal agencies of the anticipated low summer flows, especially in the Tennessee River mainstem reservoirs. Their 1988 actions included: early spring recognition of the drought probability; and early energetic information campaign, setting temporary priorities; forming a regional drought task forces and participation of State drought task forces throughout the region; comprehensive weekly monitoring of water quality and dissemination of data, developing worst-case, long-range operating strategies; and coordination of releases to supplement flows in lower Ohio and Mississippi Rivers. Given the conditions that actually occurred, TVA's early implementation of conservative management of available water resources effectively avoided many potential adverse effects of drought.[168]

WATER SUPPLY FOR THE WASHINGTON, D.C. AREA. One of the first recorded water management disputes in the United States developed over the use of the Potomac River for navigation, when the president of the Patowmack Company (which was building a canal around the Great Falls of the Potomac just upstream of what is now Washington, D.C.) invited representatives of the states of Virginia and Maryland to Mount Vernon in 1785 to arbitrate the problem. George Washington was that president, and he was able to effect a compact between the two states.[169] The most illustrative example of innovative water management in a riparian law setting revolves around the effort to supply municipal water for the metropolitan Washington, D.C. area. The challenge to water managers was to meet the needs of a growing population without a significant reservoir storage. The area experienced a much more rapid growth in population than the national average between 1930 and 1960, especially after World War II. And supply fluctuated dramatically: the average flow in the Potomac is 7 billion gallons a day, but it has been as high as 300 billion, and as low as 0.39 billion gallons per day.[170]

Phase 1: Structural solutions, fixed demands. In the first phase, which started in the 1940's, the principal actor was the Corps of Engineers. The operative planning models were flood control and hydropower generation. In 1958, the Corps was authorized to include water supply among its purposes, and in 1961, flow regulation for water quality. Each objective except hydropower was associated with a certain amount of water supply.

The Corps released reports in 1961 and 1963. The first recommended the construction of Bloomington Reservoir (renamed Jennings Randolph Lake), the second the construction of 18 major reservoirs (only 4 for flood control, the rest for recreation and low flow augmentation) and 418 smaller multi-purpose reservoirs. Jennings Randolph Reservoir, on the North Branch was authorized in 1962. The reservoir had strong local support. Construction started in 1973, and the reservoir was completed in 1981. It is the only major Corps reservoir in the Potomac River Basin.

The collective reservoir system recommended by the Corps would have produced a safe yield of 42% of the average annual flow at the District of Columbia, but they would also destroy the historic Chesapeake and Ohio Canal and would inundate thousands of acres beautiful natural habitat and agricultural lands, displace hundreds of families, and create artificial lakes with periodic drawdowns which would expose huge mudbanks.[171]

Phase 2. Environmental awareness, broader participation. The controversy over the Corps proposals was so great that then President Johnson directed the Department of the Interior to coordinate a new interdepartmental study. A year later (1965), the four governors of the basin and the President of the D.C. Council established a **Potomac River Basin Advisory Commissi** to coordinate the non-Federal viewpoint.

> *To solve Washington's water supply problem, the values, biases, and methods of different levels of government, different conceptual models (law, engineering, economics, statistics, the environmental sciences) had to be combined to find a solution which could be implemented.*

A 1968 report by the *Chief* of Engineers changed the recommendations made by the Baltimore District commander in the early 60's. The Chief's report said that *six* reservoirs would be sufficient and would be compatible with scenic and recreational values. He gave the highest priority to the construction of Sixes Bridge and Verona reservoirs, both on upper basin tributaries, which were supported by professionals and politicians in the municipal, state, and county governments.

Later that year, the Secretary of the Interior sent *his* report to Congress, saying that water quality goals should be met by better treatment, not by greater dilution. The Secretary of the Interior also backed the construction of Jennings Randolph and the six reservoirs named in the Chief's report.[172]

Phase 3. A gallon saved is a gallon stored, non-structural alternatives. A new series of studies had been initiated in 1965 as a result of the droughts which were then beginning to afflict the Northeastern United States. The Corps Northeastern Water Supply (NEWS) interim report on Potomac River Basin Water Supply, completed in 1973, made a radical departure from the earlier Corps studies.[173] Now supply *and demand* were considered as variables, either one of which could be manipulated to meet needs. The NEWS study evaluated new alternatives such as high flow skimming from the Potomac and pumping to existing reservoirs; reuse of water from the tidal portion of the river, interbasin transfers from the Rappahannock and Susquehanna Rivers, and restricting water use during emergencies. It reiterated the Chief's recommendation to build the Verona and Sixes Bridge Reservoirs and also recommended the construction of an experimental pilot treatment plant to test the feasibility of treating water from the upper (freshwater) portion of the tidal estuary.

The Water Resources Development Act of 1974 authorized construction of Verona and Sixes Bridge, the pilot treatment plant, and another study to find solutions to the WMA water supply problem. This time Congress told the Corps to have the National Academy of Sciences and Engineering review the success of the pilot plant and the water supply study.

Phase 4. Role reversal. Federal regulators versus non-Federal dam builders. Non-Federal support for the reservoirs waned, however, and the Corps stopped consideration of them. The two local suburban utilities, the Washington Suburban Sanitary Commission (WSSC) and the Fairfax County Water Authority (FCWA) began to work on their own solutions. WSSC wanted to build a weir to help draw water into its existing intake, and FCWA was planning to construct an additional intake and treatment facility to supplement its Occoquan Reservoir supply. A Corps permit was required for each project. The Corps insisted that a Low Flow Allocation Agreement be signed by the Corps' Washington Aqueduct Division (WAD), supplying the city, and the two suburban utilities, empowering any of the three to freeze the allocation formula in 1988 or thereafter. This tenet was essentially an advantage to the Corps' WAD, since its population was stable, while FCWA and WSSC had a growing customer base. The agreement was signed in 1978.

WSSC conducted a study and decided to build the Little Seneca Reservoir. EPA vetoed the Section 404 permit, saying that if all the parties in the Washington Metropolitan Area sought independent solutions to their water supply problems, then the overall environmental impact would be greater than if a regional solution were found.

Phase 5. Interstate Commission on the Potomac River Basin (ICPRB), Conjunctive Operation of Reservoirs, and Analyzing Risk. The years of study and the non-structural changes set the stage for a different attack on the problem. Past records showed that the water system would have to supply about 67 billion gallons of water during a 90 day drought. A 90 day drought is expected to recur every 50 years. It would reduce the amount of water flowing in the Potomac to only 52 billion gallons per 90-day period, leaving an unsatisfied demand of 15 billi llons of water over a 90-day period. ICPRB first developed the idea that alteration of the operations of the existing intakes and suburban reservoirs would be the equivalent to increasing the total available water supply during drought periods, in effect providing 20 billion gallons of stored water, enough to cover the deficit in flows.

The reservoirs would have to be interconnected to deliver this water. The Corps Metropolitan Washington Area water supply study underway at this time was a convenient way to test this concept.

Raw and treated water interconnections were studied. The treated water alternative called for less than the usual amount of water from suburban reservoir treatment plants to be used when flows in the Potomac were high; the difference would be used during times when Potomac flows were low. It was found that existing distribution systems could be used to handle the required flows. The Corps called the new rules "reregulation".

Risk assessment techniques were introduced when a drought on the Occoquan watershed imperiled Virginia water supply. The assessment was well enough understood by the public that voluntary use restrictions could be used instead of mandatory (and stricter) restrictions which would have reduced future risk at the cost of current use. The public gambled and won (see Hirsch, 1978, for a discussion of the risk analysis[174]).

Phase 6. Engineering models used in negotiations and drought simulations. In the late 70's, Johns Hopkins University, under a contract to the Corps of Engineers, developed the Potomac River Interactive Simulation Model (PRISM) to simulate operation of the reservoirs. PRISM was used by WMA water managers to negotiate operating policies which increased safe yields at a much lower cost than structural measures.

ICPRB formed the Section for Cooperative Water Supply Operations on the Potomac (CO-OP) in late 1979, which was a forum for the utilities to continue to work on regional solutions on scale. CO-OP revised PRISM, used it as an operating guide, and, in cooperation with others, developed a regional demand forecasting model.

The models were used again after the Washington Metropolitan Area Supply Task Force decided that it would be necessary to build the Little Seneca Reservoir to reduce the risk associated with variabilities of flows and travel times between reservoirs. That recommendation met some environmental opposition when studies showed that one or two days of very low flows would significantly damage fish habitat. Several hundred simulation runs were made on the CO OP model. Water shortages which would occur with uncoordinated operations were allocated according to each utility's own interpretation of the Low Flow Agreement and riparian law. Several hundred simulation runs were made on the CO-OP model before the utilities agreed on cost sharing for the Little Seneca Reservoir. The model was used again in 1981 in a drought management exercise. It was helpful in developing lines of communication, testing procedures, and providing up to date reassurance that the system worked. The exercise has been repeated annually ever since, for the same period.

The bottom line. In the early 60's, the Corps had proposed the construction of 18 major reservoir projects which would have increased safe yield by 42%, but with considerable environmental damage. However, on July 22, 1982, eight separate agreements were signed by the Corps of Engineers, Maryland, Virginia, the District of Columbia, two local utilities, and the Interstate Commission on the Potomac River Basin.[175] They established cost-sharing for Jennings Randolph and Little Seneca water-supply storage and WMA operating procedures.

Two new reservoirs (Jennings Randolph and Little Seneca) combined with conjunctive operation of the existing system of reservoirs increased overall system yields by over 50%, and individual project yields by as much as 200%. Water supply, instream flow, and water quality goals were met.[176]

The current solution saved approximately $200 million compared with the original recommendations, with far less disturbance to the environment.[177] A pilot water reuse plant that the Corps built was successful, in that it produced water which the Corps judged acceptable for human use, although costs are high and the National Research Council of the National Academy of Sciences has expressed concerns that current toxicological tests are inadequate.[178] [179]

The Potomac experience demonstrates:

- *the value of collaborative planning*; the values, biases, and methods of different levels of government and different conceptual models (law, engineering, economics, statistics, the environmental sciences) combined (necessarily) to find a solution;

- *the continuing support of an independent entity (CO-OP)* in order to maintain and implement water resource management and allocation in times of drought;

- *the value of credibility and objectivity in a planning/engineering team* to provide technical information and findings to the decision-making team;

- *the use of appropriate technical tools*: combined optimization and simulation techniques to provide practical rules of operation, the first large scale implementation of the National Weather Service River Forecast System, and the inclusion of water demand modeling;

- *the use of risk analysis* to identify the start of potential droughts and to quantify the risks of continued drought, and the use of a small local reservoir expressly to reduce uncertainty by covering operational forecasting errors;

- *the continuing use of drought exercises* to keep plans up to date and managers aware and practiced; and

- *the value of a good public information and involvement program.*

ALTERNATIVE STRATEGIES FOR IMPROVING THE MANAGEMENT OF WATER DURING DROUGHT

The primary objective of this study in the first year is to "examine the current methods of responding to drought nationwide and recommend a national **strategy** for better management of the nation's water resources during drought." Based on the way water is managed now, the problems we face, and the alternatives that might improve that management, what should that strategy for improvement be?

There are two related ideas which currently are supported by a portion of the water management community - the development of a national drought plan or policy, and the unification of Federal water management:

NATIONAL DROUGHT PLAN OR POLICY. The Government Accounting Office, reviewing the performance of Federal agencies after the droughts of the late 1970's, recommended the formulation of a national drought plan to provide assistance in a more timely, consistent and equitable way to drought-affected areas. The plan would identify the respective roles of agencies involved in drought response to avoid overlap & duplication, the need for legislation to more closely define these roles, any need for standby legislation to permit more timely response to drought-related problems.

In the *Drought Management and Planning* workshop, co-sponsored by the National Water Management During Drought Study, participants were asked if there should be a national policy or plan. There was some support for a national plan or policy, but also debate about who would write and implement a policy, how intrusive a plan would be on state operations and prerogatives, and what the substances would be.

UNIFIED FEDERAL WATER MANAGEMENT. Participants at the same workshop also discussed (and were also divided on) whether a national council was needed to unify Federal drought policies. Many were convinced that the lack of cohesion among the Federal agencies makes them collectively a bad choice for certain leadership roles, such as declaring that a drought has begun. Combined Federal agency involvement, such as occurs in the Catastrophic Earthquake Plan, was offered as a useful example of the type of involvement the Federal agencies should do, but most participants felt that no Federal agency had a broad enough perspective to be the single Federal point of contact for the state.

The Western Governors Association has recommended that the President should appoint a White House level group. It would be chaired by a high-level White House official, with membership drawn from departments and independent agencies with water programs. It would be an interagency forum to improve coordination of Federal water programs with each other and with state water policy.[180] The Interstate Conference on Water Policy published a concept paper in February, 1990, which proposed a President's Council on Water, with state and regional members relying mostly on ad hoc committees for appropriate expertise.[181] Following the drought of the 1970's, a recommendation for a single Federal coordinating body for *all* drought programs was made.[182] [183]

BETTER PIECES, BETTER PLANNING. In addition to the two unifying propositions described above, there have been a number of suggestions on individual approaches which could be applied nationally.

A report published following a National Science Foundation Workshop on Drought in November, 1988 recommended that the best approach would include the establishment of drought planning as a continuing process (including expanded knowledge of climatic changes, continued vigilance with sensitive warning systems, strategies that increase resilience and sustain our resource base). It would include a Federal effort to improve data management capabilities (analysis, integration and interpretive presentation), a multi-level government program to educate the public; and a streamlining of existing administrative structures.[184] This follows the planning recommendations from an earlier symposium,[185] which recommended that drought-planning should include:

- Monitoring/early warning system to provide decision-makers with information about the onset, continuation, and termination of drought conditions and severity;

- Operational assessment programs to reliably determine the likely impact of the drought;

- An institutional structure for coordinating governmental actions, including information flow within and between different levels of government;

- Drought declaration and revocation criteria;

- Appropriate drought assistance programs with predetermined eligibility and implementation criteria;

- Financial resources to maintain operation programs and initiate research required to support drought assessment and response activities; and

- Educational programs designed to promote the adoption of appropriate drought mitigation strategies among the various economic sectors most affected by drought.

Others have recommended:

- Better impact assessment,[186] [187] [188] including reservoir simulation models which allow managers to determine the relationship between operation and impacts of reservoirs more easily;[189]

- Changes in law;

- The construction of additional water storage and control facilities;

- The reallocation of existing storage;

- Encouragement of conservation;

- Setting of explicit priorities for water use purposes;

- Improvement of our knowledge of low flow hydrology

- Better drought indicators and forecasting methods; and

- Increased use of conflict resolution, negotiation techniques, decision support software, risk assessment, and drought exercises.

<u>Within the Corps of Engineers,</u> suggestions have included:

- Revision of the principal Corps regulations on drought;

- Clear and broadly available explanations of Corps authorities and programs;

- The transfer of information on lessons learned from the southeast drought to Corps district and division offices in other regions;

- The need for better drought contingency plans;

- The importance of drought management committees;

- The value of water supply and use data, up-to-date water control manuals and reservoir rule curves for low-flow operations;

- Use of simulation models for assessing impacts;

- Open communication and public information;

- Development of Memoranda of Agreement between Corps and other institutions;

- Drought monitoring and response plans; and

- The value of division and district drought coordination.[190] [191] Some of these suggestions have already been enacted.

EVALUATION OF ALTERNATIVE STRATEGIES

The recommendations to meet the primary objective of this study have been formulated taking into account the suggestions others have made for strategic approaches, recommendations for tactics which should be applied nationally, and analysis of regional experiences with drought.

The gap between action and need may be explained by these observations:

> Major changes in any complex system tend to be resisted because there is no guarantee that the new system would work better, and there is a possibility that things could get worse;
>
> There is less examination of the entire system than there is of individual parts of the system because it is difficult to comprehend a system as a whole. This is a corollary to the fact that there is no entity dedicated to improving the performance of the system;
>
> "Losers" can identify their losses, "winners" gains are more diffuse;
>
> Drought is a problem whose immediate impacts are almost always regional, and there is great reluctance to impose "one size fits all" national solutions;

While particular measures may not be nationally applicable, whole system management is. The lack of attention to the study and management of the entire system is clear. This has the effect of making solutions to water problems time consuming and difficult.

In beginning the study of a hypothetical regional water management during drought problem, one might list (say) 1000 different possible ways to solve the problem. Except for those rare solutions which require no approval or funding, each of the 1000 possible solutions would have to be evaluated in the abstract by professionals trained in the use of specific analytical models. Although there is no universal recipe for combining these models, typically a solution could be examined by local politicians, a Federal or state water development agency, environmental groups, state and Federal politicians, Federal and state regulatory agencies, the interested public, industrial, and commercial sectors, and (if all else fails) the courts.

The hierarchy of water management principles (see Section II) would define which of the models and practitioners had dominance when there was a direct conflict in the analysis of an idea, but there is little formal guidance on how the entire process should be managed to select the best solution. The current set of rules is, *de facto*, a water policy, but it is more labyrinth than guiding path.

> *The current set of rules is, de facto, a water policy, but it is more labyrinth than guiding path.*

Quite often, water management actions start and incubate within one portion of the matrix, where goals and preliminary recommendations (marked by the characteristics of the incubating entity) are formed. The nascent idea is then pushed out to suffer the attacks from the rest of the water management matrix, as each element separately pursues its legal or ethical obligations. Major decisions may take decades, with all parties suffering in the interim [No conservation measures taken, no dams built, water supply vulnerability]. Within the hierarchy, stalemates are elevated. Practices which are contested are elevated to reviews of policy. Policies are protested to Governors and Congressmen, and everything can ultimately be thrown into the court system to decide.

There is a growing body of research and case studies (such as the Potomac River Basin) that describe a synthesis of these models for water management; it is marked by negotiation, and the efficient use of engineering and economic models. It recognizes the need to think analytically about risks.

But the use of this integrated management is the exception. The regions which have chosen to integrate the different perspectives on water management during drought have usually done so when confronted with the most immediate, significant drought problems, or after having suffered through decades of recommendations which were unable to elicit support necessary for implementation.

The national strategy to improve water management during drought must include the things that are done best on the national level: study of system improvements, sharing of successes and failures, research on concerns. It should be well grounded and tested so as to address the arguments for not changing. The recommendations for the next two years of study reflect those requirements.

V. Conclusions and Recommendations

Conclusions

1. **Much has been done in the United States to reduce vulnerability to drought** since the great droughts of the 1930's. But the goal of minimal impacts is a moving target because demands can increase and diversify, and, as with all issues surrounding the human adaptation of the world to specific human purposes, there is a substantial debate about what constitutes success.

2. **Future impacts of drought are likely to be more serious than the immediate impacts from the 1988 drought** because in some areas, we had plentiful water and we had large stores of grain when the drought started. Many places in the country are *chronically ill prepared* for drought. These problems will be exacerbated if, as some studies suggest, global warming increases the severity and frequency of droughts in the U.S.

3. **Most experts agree that better planning, better data, better analytical techniques, and a more coordinated, cooperative and communicative response would improve water management during drought.**

4. **No consensus exists within the water management community on a national strategy to improve water management during drought.** Disagreements are based on differences in perspective, experience, and responsibilities. There is a limited amount of study devoted to the integration of the many pieces of this complex issue. There is also a resistance to strategy changes in a system as large and complex as the water management system.

5. **No single conceptual model, in law, engineering, economics, the social or environmental sciences, encompasses the reality of drought.** No single profession or institution can manage water during drought solely within its purview. A region interested in reducing the impacts of drought should find a way to effectively and efficiently include all these perspectives and concepts in its planning.

6. **Regional differences are substantial,** in needs, law, climate, and level of investment. National policies (to the extent that they will ever be spelled out) must reflect the diversity of situations within the 50 states.

7. **The nation should find better ways to share success stories and technical advances among regions,** despite the regional differences. This is especially true for overall drought preparedness strategies, water conservation, and demand forecasting. The collaborative problem-solving approach is not used enough.

8. **The application of water conservation principles is spotty.** The reduction of the demand for water is being used more and more often as an alternative to new supply, but when supply is considered adequate, the costs savings which are available (such as reduced treatment costs on a municipal level, and reduced energy costs on a household level) are often ignored. Techniques which estimate the effectiveness of proposed water conservation measures have been developed and tested, but are not widely enough used.

9. **Some basic questions about drought preparedness are unanswered,** such as "how big a drought should we plan for?", or, "how much is it worth to reduce our vulnerability?" Unlike floods and other natural disasters, droughts are difficult to plan for, based on specific scenario drought events. There are many significant variables to consider during a drought, and typically not enough is known about the recurrence intervals. Since there are often too many drought scenarios to consider, and uncertain levels of risk for each scenario, most drought planning is oriented towards a decision process.

10. Streamflow forecasting and risk-based decision-making techniques have the potential to provide water managers valuable tools with which to prepare for drought. However, application of this synthesis of models is not widespread.

11. Some regions have a greater need and a greater willingness to change than others, and the Corps is in a better position to help in some places than others. Regions which have recently gone through a serious drought, and regions in which the major users and managers believe that change could benefit everyone are more likely to rethink water management methods.

12. The Corps is more capable of helping a region plan for drought when the Corps already has the experience that comes from having an important planning or operating role in the region; it will only be successful in helping a region plan for drought when non-Corps water managers welcome Corps involvement.

13. Some changes are so fundamental that they cannot be rushed. Current laws and institutions are not ideally suited to managing current and future water management challenges, most water managers agree that what we have needs revision. But such fundamental changes tend to be resisted because no one can predict their ultimate effect, and current stakeholders might be hurt.

14. Funding and staffing for drought planning face stiff competition with other important concerns at all levels of government. Not enough is known about how to strategically prepare for droughts so that the maximum benefits can be derived from the minimum expenditures, these uncertainties come from the difficulty in quantifying expected values of benefits, and from difficulties in prioritizing the worth of types of solutions.

Recommendations

Based on the conclusions listed above, and consistent with the primary study objective to develop a strategy for improving water management during drought in this country, we offer the following recommendations:

1. Develop *Drought Preparedness Studies (DPS)* during the remaining three years of the study in four river basis: the Kanawha (West Virginia), James (Virginia), Cedar/Green (Washington), and Marais des Cygnes-Osage (Kansas-Missouri).

Each DPS will be designed to address a regional drought problem. Collectively, the DPS's will be used to develop a planning guide which other regions can use to prepare for drought. The DPS's will add to the water management community's experience with system management. These studies may provide opportunities to aid the development of national drought policies. The majority of the remaining time and funding of this study will be devoted to the conduct of these studies.

Each DPS will address the questions: *how does this region want to be positioned for future droughts? and what can the region do now to mitigate impacts of future drought?* All the perspectives associated with the problem of drought will be included in the strategy developing process.

Each study includes the formation of a study group representing water managers, users, and other interested parties. Points that will be addressed in each study include:

- development of a statement of goals and objectives which address the values and needs of all the participants;
- an assessment of vulnerability under the *status quo*;
- an evaluation of available data and technical tools;
- the development of a public involvement and education plan, legal and institutional reviews to determine if changes in those areas would contribute to the goals of the DPS;
- development of a plan for water management during drought under the new strategy; and
- formulation of a drought exercise program to maintain staff familiarity with drought issues and to assure that the strategy did not become dated as situations in the region changed. Drought preparedness efforts will not end when the studies are over.

Each DPS will be tailored to meet the needs of the region. Some studies will need more time and money on the development of an organization that brings stakeholders into negotiation. Others will concentrate on the development of technical tools and public involvement. Each will benefit from the success stories and technical advances that have been used elsewhere. The National Water Management During Drought Study will continue to develop the network of water managers nationwide who can both contribute to and study these regional efforts. State agency water managers, among others, will provide an important contribution to these studies.

2. Prepare a *National Drought Atlas*.

Not enough is known, and less is shared, about the probability that droughts of a certain duration or length will occur That ignorance has significant planning consequences because no one knows how big a drought for which to plan. The Atlas will be a book of tables, charts and maps that illustrate historical drought in frequency terms that can be used as a source of information for drought planning. The frequencies of precipitation, Palmer indices (indices of soil moisture), and streamflow will be presented for all climatic regions of the United States for durations and areas appropriate to that region. The Atlas will be prepared jointly by those Federal agencies charged with the responsibility for these data: the National Oceanographic and Atmospheric Administration's National Climate Data Center for precipitation, and Palmer indices; the United States Geological Survey (USGS) for streamflow. Once published, the Atlas will outline the state of the art in the presentation of historic drought records. But because of the inherent difficulties in analyzing historical drought records and applying them to current planning, the Atlas will also expose what we do *not* know. As such, it will serve as a point of departure for regional frequency analyses and future research to improve on the state of the art.

Other information will be included in the Atlas. For example, available tree-ring records will be presented to supplement as much as possible the historic records. Also, discharges on regulated rivers will be examined to see if useable information can be presented, such as in the Tennessee Valley River Basin, where TVA has one-day minimum flow records.

3. Prepare Topical Studies.

Topical studies will be conducted in conjunction with four DPS's in the areas of planning methodologies, law, institutional analysis, engineering, economics, environment, other hard to quantify impacts, financial analysis, public involvement, negotiation and dispute resolution, risk assessment and management, and decision making. The aim of these studies will be to provide a basis for the selection and prioritization of the application of these tools for drought preparation.

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Appendix A

Study Coordination and Participants

The steering committee for the study was comprised of Corps of Engineer Division Chiefs and Directors of Planning, Engineering and Operations. Division staff provided direction early in the study along with conveying the Division's perspectives on drought and water management.

In April 1989, prior to the start of the study, Corps and non-Corps water managers met in Atlanta to develop a plan to meet the broad study objectives. Participants in this workshop were:

> Dr. John Boland (Johns Hopkins University); Dave Buelow (HQUSACE); Ed Burkett (Mobile District); Suzanne Butterfield (California Dept. Water Resources); Dick Eng (South Pacific Division); Rich Furman (Ohio River Div.); Joe Goode (South Atlantic Div.); Randy Hanchey (then WRSC, now Lower Mississippi Valley Div.); Bert Holler (South Atlantic Div.); Ray Jaren (North Pacific Div.); Norwyn Johnson (Lower Mississippi Valley Div.); Harry Kitch (HQUSACE); Paul Pronovost (New England Div.); Don Sedrel (Missouri River Div.); Dr. Daniel Sheer (Water Resources Management,Inc.); Vic Smith (South Atlantic Div.); Dr. Bob Summitt (Southwestern Div.); Donald Vonnahme (Illinois Div. Water Resources); Gary Wickboldt (North Central Div.); Chet Worm (Missouri River Div.); Ron Yates (Ohio River Div.)

Corps and non-Corps professionals participated in the Corps Perspective Workshop in Phoenix, Arizona, January 1990. These individuals, who continued to provide technical assistance and substantial advice throughout the study, were:

> Dr. Duane Baumann (Planning & Management Consultants Ltd.(PMCL)); Dr. Robert Brumbaugh (IWR); Dave Buelow (HQUSACE); Mike Burnham (HEC); Dr. Ernie Carlson IWR); Pat Davis (South Atlantic Div.); Dr. Benjamin Dziegielewski (PMCL); Rich Furman (Ohio River Div.); Ralph Garland (Southwestern Div.); Joe Goode (South Atlantic Div.); Dr. Neil Grigg (Colorado St. Univ.); Ray Jaren (North Pacific Div.); Bill Johnson (HEC); Norwyn Johnson (Lower Mississippi Valley Div.); Mike Kidby (HQUSACE); Bob Kaighn (Office Ass't Sec. Army, Civil Works (OASA(CW)); Harry Kitch (HQUSACE); Charles Lancaster, J.D. (Univ. Virginia); Roy McAllister (Missouri River Div.); Zoltan Montvai (HQUSACE); Curt Musgrave (Missouri River Div.); Tom Phillips (Bureau of Reclamation); Paul Pronovost (New England Div.); Kyle Schilling (IWR); Warren Sharp (Lower Mississippi Valley Div.); Fred Snyder (Missouri River Div.); Dr. Bob Summitt (Southwestern Div.); Mike Thompson (New York District); Ming Tseng (HQUSACE); John Vento (North Central Div.); Pat Witherspoon (South Pacific Div.); Bill Werick (IWR); Gary Wickboldt (North Central Div.); Dr. Donald Wilhite (Int'l Drought Info. Center, Univ. Nebraska); Tony Willardson (Western States Water Council); Dr. Gene Willeke (Miami Univ.); Chester Worm (Missouri River Div.); Ron Yates (Ohio River Div.); Paul Zepernick (North Pacific Div.)

The study effort also relied on the substantial technical assistance and insight of several other people from IWR including Dr. Jerry Delli Priscoli (Alternative Dispute Resolution), Darrell Nolton (Water Conservation), Arlene Nurthen (Publications Director) and Dr. Mark Dunning (Public Participation); from Corps headquarters including Earl Eiker and Dick DiBuono (Hydrology & Hydraulics), Ron Allen (Counsel), Rich Worthington (Policy), Mike Hartley (Operations), Dave Hewitt (Public Affairs), and Marty Reuss (Historian); and from Corps divisions and districts, including Arvid Thomsen (Missouri River Div., Planning), Bill Pearson

(Southwestern Di ., Planning), and Noel Beegle (Baltimore District, Planning). The consulting firm, Planning and Management Consultants, Ltd., provided an assessment of current knowledge and practice regarding water management during drought. Bruce McDowell, Director of Government Policy Research for the Advisory Council on Intergovernmental Relations provided a valuable overview of the history of intergovernmental coordination and water management. Throughout the study, the Hydrologic Engineering Center provided insight into water management issues and developed a preliminary assessment of Corps reservoirs, their purposes, and susceptibility to drought.

Many Federal agencies responded to our call for assistance during the course of this study. Among them, special thanks are extended to Clive Walker (SCS), to Tom Phillips (Bureau of Reclamation), Dr. Nathaniel Guttman (NCDC, NOAA), Gene Stallings (NOAA) and Wilbert Thomas (USGS)

Thanks also go to all those state officials and water managers who provided their individual state perspectives regarding water management and drought issues. The following list includes those designated by their respective governors and those additional staff who provided input. With apologies to those we have omitted, they included:

> Lennie Gorsuch (Alaska); Walter Stevenson, Jr. (Alabama); J. Randy Young (Arkansas); N. W. Plummer (Arizona); Suzanne Butterfield and Deborah Braver (California); Joan Maloney and John Radasci (Connecticut); Alan Farling (Delaware); Rick Smith (Florida); Nolton Johnson (Georgia); William Paty and Paul Horaquwche (Hawaii); Allan Stokes (Iowa); Keith Higginson (Idaho); Donald Vonnahme (Illinois); John Simpson and Jim Hebenstreit (Indiana); Joe Harkins and Thomas Stiles (Kansas); Leon Smothers and Pam Wood (Kentucky); Neil Wagoner and Curtis Patterson (Louisiana); Elizabeth Kline (Massachusetts); Gary Setzer (Maryland); David Brown (Maine); Dennis Hall (Michigan); Ron Nargang (Minnesota); G. Tracy Mehan, Ron Kucera, and Steve McIntosh (Missouri); Jimmy Palmer (Mississippi), Gary Fritz and Curt Martin (Montana), John Morris and Woodrow Yonts (North Carolina); David Sprynczynatyk (North Dakota); George Beattie (Nebraska); Delbert Downing and Ken Stern (New Hampshire), Melvin Hartman, Steven Nieswand, and Paul Schorr (New Jersey); Philip Mutz (New Mexico); Peter Morros (Nevada); Russell Mt. Pleasant and Harold Budka (New York); Dale Shipley and Dick Bartz (Ohio); Glenn Sullivan (Oklahoma); William Young and Barry Norris (Oregon); John McSparran and Joe Hoffman (Pennsylvania); Robert Griffith, Jr. (Rhode Island); Alfred Vang and Hank Stallworth (South Carolina); Tim Edman (South Dakota); Jim Hall and Allan Coggins (Tennessee); Robert Johnson (Texas); Larry Anderson (Utah); Dale Jones (Virginia); George Lowe (Vermont), Hedia Adelsman and Doug McChesney (Washington), Alan Tracy (Wisconsin); Dr. Eli McCoy (West Virginia); and Gordon Fassett and Frank Trelease (Wyoming).

Several workshops, in addition to the Corps Perspective workshop, provided input instrumental to the study. Thanks are extended to Dr. Donald Wilhite who organized and chaired the Drought Management and Planning, Today and Tomorrow Seminar and Workshop in Denver, Colorado, May 1990, and to D. Craig Bell who organized the Drought Workshop for the Western Governors' Association (WGA)/Western States Water Council (WSWC) in Houston, April 1990. Tony Willardson (WSWC) and Jo Clark and Kristen Dillon (WGA) provided valuable insight to this study in addition to their efforts at the workshop.

Other organizations who invited us to attend their meetings and who variously provided input to the study include the Interstate Conference on Water Policy (especially Donald Vonnahme, chair of the Drought Committee, the Missouri Basin States Association, the Upper Mississippi River Basin Association, the Great Lakes Commission Drought Task Force, the Ohio River Basin Commission, the Susquehanna River Basin Commission, the Delaware River Basin Commission, the South Florida Water Management District (especially Bruce Adams and Dr. Steve Light), and Dr. Roland Steiner, Associate Director of the Interstate Commission on the Potomac River Basin.

Appendix B

The Objectives of the Drought Preparedness Study

Drought Preparedness Studies (DPS's) must satisfy two objectives:

> to help achieve the principal objective of the National Study of Water Management During Drought, which is to develop a better way to manage water during drought in the United States;
>
> to leave the region better prepared for drought.

These objectives must be taken together in managing the conduct of the DPS's. The first, national objective requires that regional goals must be met through thorough and innovative methods whose application and testing will advance the nation's ability to prepare for drought. The regional objective imposes a standard of practicality; each DPS must be more than just a good national research project; it must produce a tangible regional benefit.

How the DPS's can help fulfill the primary objective of the National Study of Water Management During Drought. Many others who have studied the performance of water management systems during drought have described the same or similar weaknesses we reported. They have advocated specific changes in policy, institutional organization, or standards of practice. The recommendations others have made for systemic change have encountered a wall of resistance, and many of the important recommendations have not been implemented. The resistance to change comes because of a lack of understanding of the system as a whole (most people work in just part of the system), disagreement on specific changes, and the fact that no one can guarantee that the "improved" system will work better than the system we have now. A strategy to improve water management has to overcome the lack of **knowledge, consensus, and confidence.** It is clear that reports, by themselves, have not led to significant change. We believe that demonstration studies which involve the water management community and which apply and test innovative ideas offer a realistic chance for overcoming those three barriers.

The Concepts Which Distinguish a DPS

The DPS incorporates the best traditional and innovative methods of water resources planning. There are already a variety of named, recognizable planning efforts which help mitigate drought impacts, including Corps feasibility studies, reallocation studies, and drought contingency plans. Other federal agencies have similar methods. In addition, about half the states now have written drought contingency plans.

The DPS can be distinguished from these efforts by the specific concepts which address the problems in the way we currently respond to drought, as reported to, and analyzed by the National Drought Study team. Those concepts are:

Concept: DPS's should have performance, not agency mission goals. There is no single American Department of Water which concerns itself with everything having to do with water . Even if there were, the responsibility would have to be broken down into component parts to be manageable. In fact, there are hundreds of such components in the American water management system. The Environmental Protection Agency worries about water quality. The Bureau of Reclamation thinks about capturing surface water. USGS keeps track of surface an d groundwater statistics, but it is the states that do most of the groundwater supply management. The satisfaction of the need for a glass of water may require the coordination of a private utility with Federal, state, regional, and local government agencies, each with its own mission. But is the best balance of clean, safe, delicious, cheap and plentiful water assured by each agency pursuing its individual mission?

William Blomquist, writing for the American Council on Intergovernmental Relations, distinguishes between *functional* management, aimed at assuring that needs are met, and *institutional* management, which is geared to assuring that an agency fulfills its mission. While the two are conceptually compatible, pursuit of individual agency goals, using agency specific approaches, may permit things to fall between the cracks, and may introduce delays and inefficiencies for which no agency has to individually account.

Application: This does not diminish the obligation of agencies to fulfill their missions, or the necessity of involving mission oriented agencies in customer oriented planning efforts. An agency or group should be included from the beginning of a DPS if it:

- has been given a specific drought related responsibility by a legislature;
- represents a perspective with intellectual, political, or judicial weight;
- possesses skills which can help solve problems;
- will be affected by drought.

One area where Drought Preparedness Studies will be obviously more customer oriented than agency mission oriented is in the formulation and evaluation of alternatives. ***That does not imply a shift in policy as to what constitutes the Federal interest, or the Corps obligation to represent it***, anymore than the American Medical Association's new recognition of the importance of diet and exercise implies that their members are no longer doctors of *medicine*. What it means is that in conceptualizing problems and formulating alternatives, those involved in a DPS will act as a citizens' group. For those of us in the Corps, our special contribution will be our knowledge of water resources planning and the specific ways in which the Corps is authorized to act to meet the functional needs.

Concept: DPS's must incorporate three types of reaction to drought.

The plethora of responses towards water shortages can be categorized as emergency, tactical, or strategic. A plan may have elements from more than one category.

Element of Response	Examples of Application
Emergency measures are those which are necessary when the preparations made prove not to be sufficient, when something happe ns which was improbable enough that there was little or no investment in avoiding its impacts.	A city's response to an oil spill which will require the closure of its main water intake s, or an earthquake which destroys water supply lines. The type of planning the Corps is required to do under Executive Order 12656. The Corps "emergency" authorities which allow it to help drought stricken areas when every other means has been exhausted.
Tactical measures are planned procedures which are implementable within the framework of existing laws, institutional arrangements, and infrastructure, and which are set into place before drought occurs again. Good tactical measures include the prediction of vulnerability, identification of programs and agencies which can help alleviate drought impacts, and creation and exercise of a coordinating plan to assure th e full effectiveness of the arsenal of mitigat ive measures which are available.	About half the states now have at a drought contingency plan (DCP). Most state plans are basically tactical, with a few significant exceptions. The Corps DCP's performed under the guidance of ER 1110-2-1941 can be strategic (look at opportunities for reallocation), but are often mainly tactical, usually because of low levels of funding.
Strategic measures are planned procedures which allow for the modification of existin g laws, institutional arrangements, and infrastructure to meet planning objectives.	Corps studies which tend to be progressivel y more strategic, less tactical: Revisions of reservoir operating manuals; reallocation studies; reconnaissance and feasibility studies. A few states (Florida and Arizona, e.g.) have made sweeping changes in their legal systems to better address water management needs.

Concept: DPS's must be linked strongly to the National Drought Study. There are two reasons for the link. First, the collective, national objective of the DPS program, to improve the way water is managed during drought in the United States, can be achieved only if the experiences of each DPS is shared with those *not* directly involved in a DPS. Second, both the national and regional objectives require access to a national pool of expertise and innovative methodologies and state of the art analytic tools. There is disagreement about how much research should be funded to improve analytic models, but there is little question that a broader application of the best current analytic techniques in an integrated, customer oriented study would improve drought preparation at a minimal cost.

Application: IWR will aggressively connect researchers working on specific problems in wat er management with the people involved in the conduct of the DPS's. Assistance will be provided in the form of manuals and computer programs, expert counsel, and information sharing workshops. In addition, there will be a deliberate effort to keep all the districts conducting DPS's in communication with each other, both directly and through IWR. IWR will publish a monthly newsletter tracking the progress of the DPS's and other efforts that are part of the national study.

The Outline of a DPS

Overview. A DPS is a cost-efficient, multi-objective, multi-agency, regional or basin wide study, with a regional and a national objective. The **regional objective** is to produce a Drought Preparedness Plan with emergency, tactical, and strategic responses to regional droughts. These plans will:

> define the nature of the drought induced water management *problems*;
>
> define the relative *roles and responsibilities* of the various entities and institutions concerned with the mitigation of drought impacts;
>
> develop alternative management *measures* that more effectively and efficiently deal with drought impacts, and that effectively weave together emergency, tactical, and strategic response elements.

Each year of a DPS will be captured in a summary report which would aid in decision making if a drought were to occur in the following year. The final DPS report will include the final Drought Preparedness Plan, and a long term strategy for reducing regional drought vulnerability, including ways to keep the Drought Preparedness Plan vital and up to date.

In addition each DPS must contribute to the **national objective** of the DPS program, which is to engage the water management community in a demonstration and test of innovative approaches and methodologies leading to (1) a reference work on preparing for drought (2) support for national changes in policy or practice to the extent that the need for those changes is supported by the experiences of the DPS program.

Scope. The DPS's will be conducted simultaneously in Fiscal Years (FY) 91 through 93. From a funding and manpower perspective, the first year of each DPS will essentially be the product of six months of one district person's work. The district manager will spend about half that time in research (literature review, interviews, and the production of an annotated bibliography), one fourth in meetings, and one fourth in writing a summary report. A generic first year report outline is an appendix to this guide.

The report will summarize the drought problems facing the area, the perspectives on problems and alternatives, the quality and quantity of existing analytical models, a preliminary evaluation of the alternatives, and a strategy for the future, including a scope of work for the remainder of the DPS. In addition to the summary report, the first year will result in the development of a regional working group and an informed scope of work for the remainder of the DPS.

A DPS is not a reallocation or a reconnaissance study. A successful DPS may lead directly to some specific actions at the Federal level, but these are not Congressionally authorized implementation studies, nor is there a commitment or suggestion that specific Federal actions must follow.

Each DPS represents a limited opportunity to solve real problems. The challenge will be to find the vulnerabilities that are most important, and the approaches that are most effective in reducing those vulnerabilities. The working group on each DPS will have to make difficult choices in the ranking of impacts, roadblocks, and the selection of a study path most likely to find the best alternatives and recommendations. Allocation of study resources to the areas with the biggest likely payback is critical.

The first year's analysis is extremely important for the success of the DPS and the efforts which follow the DPS. The DPS's will be pursued according to an iterative application of the modified P&G[1] methodology outlined below, broad in the beginning, and focused towards the end. In this specific regard, the DPS will be very familiar to Corps planners.

We expect that the DPS's will differ in some significant ways from each other after the first year, but in general we expect each DPS to produce a mixture of actual solutions (perhaps a mainly tactical Drought Contingency Plan) and recommendations for future strategic action.

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1. Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies published by the U.S. Water Resources Council in 1983.

The generic first year study outline. The following steps describe the activities which might take place in the first year of a DPS, with some examples of techniques provided.

1. The district engineer signs a letter prepared by the district manager announcing the study. The letter is addressed to universities, environmental groups, cities, utilities, etc. A standard checklist and a generic letter are included in appendix to this guide. The letter will explain the background and announce the start of the DPS; ask for information, studies, and models; and invite participation.

2. The district manager begins a 4 month review of existing reports, extensively augmented by interviews, small meetings, and phone calls to the parties identified in the initial mailing and through subsequent contacts. The manager keeps a bibliography and directory/mailing list, and writes and revises the summary report simultaneously. A modified P&G methodology guides this pursuit of information, and organizes the developing report. The DPS, over the course of three years, will reiterate these steps, providing more information, in greater detail, with more cohesive analysis. The steps are described below in terms of what is ultimately needed. The first iteration, based on a literature review, interviews, and small meetings will necessarily be less accurate and well founded that later iterations:

a. **Specify problems and opportunities.**

b. **Identify decision criteria.**

c. **Inventory and forecast water and related land resource conditions.**

d. **Formulate alternative plans.**

e. **Evaluate the effects of the alternatives.**

f. **Compare alternatives.**

g. **Make recommendations**

During these four months, the district manager, now with a better understanding of the issues and interested parties, begins to ask specific people if they would like to serve on a working group for the duration of the DPS. The working group should be made up of people who represent a cross section of managers, users, and issues advocacy groups in the basin. They will participate in the every part of the study to the limit of their willingness and expertise. The contributions this group makes will include, but need not be limited to review of interim reports, telephonic consultation on study issues, advice on or provision of additional sources of information or analysis, and attendance at two study workshops during the first year.

3. At the end of four months, the district manager releases the developing summary report, in draft, with blanks where the information is not accessible. The report is circulated among those on the mailing list with a cover letter calling for a workshop, an agenda, and a request to review the report.

4. The district manager will plan and call the first workshop of all the parties which have been identified to date. The objectives of the workshop will be to:

> Formalize a working group relationship. What is the role of each member? Who else should be included? What are the mechanisms for staying abreast of developments?
>
> Clarify understanding of the DPS process. What are the goals and timetable? What is possible? What will happen when the DPS is over?
>
> Improve the interim report. The working group can debate conclusions presented in the report, suggest new sources of information to strengthen the report analysis, or reach consensus on issues

5. The district manager documents the results of the workshop and develops an approach to determining the seriousness of the problems, and ways to test alternatives, taking advantage of the national study team and a team of national experts to custom tailor some approaches in the areas of planning methodologies, political analysis, law, organizational analysis, engineering, economics, environmental impacts, other hard to quantify impacts, financial analysis, public involvement, negotiation and dispute resolution, risk assessment and management, and decision making.

6. This cycle of research, reporting and a workshop is repeated once more to assure that the working group and the study manager have clearly stated the issues and delineated the areas of consensus and controversy. After the second workshop, the district manager writes the first year report. The report includes a plan of study for the next two years, and a description of long term challenges and goals.

The next few pages describe each of the steps a-g in the modified P&G shown in paragraph 2, above.

Planning Element	Work Description - 1991
Level and type of effort	*Based on a literature review and discussions with water management experts. Synthesis through two regional workshops and review of a draft report.*
a. Specify problems and opportunities.	Identify the major perspectives on drought in the region (agency by agency, user by user). Describe past impacts and the efforts to mitigate those impacts, from each perspective. What actions were taken to minimize future impacts? What were the shortcomings? Why is the region vulnerable despite these efforts? What benefits could the region realize if its vulnerability to drought were reduced. Against that setting, create a first set of objectives - statements about what a DPS *could* do to reduce impacts and allow the region to endure future droughts with less difficulty.
b. Identify decision criteria. This adds a defensible, structured mechanism for developing and evaluating tradeoffs.	Start with the longest list of motivational factors for drought related behavior, including these types of criteria: institutional, political, economic, financial, environmental, social, aesthetic, risk-aversion (redundancy). Search for independent criteria, and assess weights interactively, in workshops and interviews. It would not be necessary or advisable to over simplify these factors in the beginning of the study so there is one set of criteria and weights which can be applied to all those affected by drought; in fact, separate sets of weights or priorities should be kept for different actors at this point.
c. Inventory and forecast water and related land resource conditions.	Describe what would most likely happen if no alternatives are pursued. Describe the models and data sources which substantiate or suggest these consequences. Quantify or describe the uncertainty in the estimates created by the *lack* of data and modelling capability. Determine what drought contingency plans have already been implemented, and how effective they might be.

Planning Element	Work Description - 1991
c. Inventory and forecast (continued)	Create a series of tables. On the **summary** table, in the first column, list different sizes of droughts, using historical droughts but extending the range with larger droughts (using tree ring records and the advice of regional climatologists and the National Drought Atlas staff). Table headings used to define and describe the different sized droughts could include a **meteorological definition,** or a mixed **meteorological** and **hydrological** definition, associated **impacts** (actual and projected), **probability** of occurrence, the level of certainty about the region's **readiness** (based on available demand and supply projections, assessments of drought contingency plans, and related issues such as declining tax base, water quality concerns, etc.), and the **risks associated** with any shortcomings in regional readiness. Back up the summary table with information on **demand** (current, forecasted, and supply (surface and groundwater, contracts, potential emergency sources), impacts by use (recreation, hydropower, in-stream, M&I, navigation, etc.) and current constraints (financial, legal, institutional, infrastructural).
d. Formulate alternative plans.	Create another table. In the left column, list all the "actors" in a drought: Federal agencies, states, municipalities, vulnerable industries and commercial entities, environmental groups, user groups, etc. Develop a list of all the things which might be done to reduce the impacts of drought, such as pre-established tactical response measures, public awareness programs, structural methods, and long term conservation measures such as changes in land management or plumbing codes. Include both independent actions (taken by one city, one utility), and coordinated actions which would help prepare the region for drought.

Planning Element	Work Description - 1991
e. Evaluate the effects of the alternatives.	The table prepared in step b. (identify decision criteria) describes the types of potential impacts. How much will the impacts be reduced by each alternative? The problem and opportunity statements describe the previous roadblocks to preparing to reduce those impacts. Do the alternatives address those roadblocks? The criteria for acceptability to each entity have been spelled out and weighted. Evaluate the alternatives from the perspective of each entity's weighted criteria. Then group the criteria, alternatives, and players and evaluate the generalized alternatives. (This analysis will come later in the first year; more details on how this might be done will be provided before then.)
f. Compare alternatives.	Look at alternatives in sets and alone, matched against the criteria. Which offers the most promise in reducing risks and avoiding impacts? Which optimizes performance for costs?
g. Recommend specific actions.	Write a summary report on your preliminary analysis. Describe the vulnerabilities in the region, the roadblocks to reducing potential impacts, and alternative approaches and the alternative futures they would make possible. Discuss how the region can achieve its long and short term goals for the reduction in drought vulnerability. Develop a scope of work for the next two years of the DPS, and explain the effectiveness of that scope in achieving regional goals. Describe actions which would help achieve strategic goals which might follow the DPS. Subsequent phases might be the imposition of conservation laws, initiation of a reallocation study, or a Section 22 investigation into conjunctive management. Describe the Drought Preparedness Plan as it currently stands and the work that remains to be done.

Drought Preparedness Study

Report Outline

Chapter

Executive Summary

I. Introduction

- The National Study of Water Management During Drought
- Concept of a Drought Preparedness Study
- The Four DPS's
- Geographic scope of this study
- Study Participants

II. Problems and Opportunities

- The natural phenomenon of drought
  - Previous droughts in the region
  - Probability, Severity, and Duration of Future Droughts in the Region
- Human impacts and responses to drought
  - History of water management in the basin
  - Principle water management agencies in the regions
  - Principle water users in the region
  - Advocacy groups and other third parties
  - Impacts from historic droughts in the region
  - Past actions implemented as a result of those droughts
  - Areas of vulnerability to future droughts
- Planning objectives for this DPS

III. Measuring the Effects of Drought in the Region; Identification of Decision Criteria

- Decision criteria of the principal agencies, users, and third parties
- Relative weights assigned to these factors by the principals

Drought Preparedness Study

Report Outline

Chapter

IV. Inventory and Forecast of Water and Related Land Resource Conditions

Current drought contingency plans
Water demand forecasts for the region
Water quality issues during drought
Significant existing constraints which limit the region's ability to respond to drought
Probable drought impacts if no further actions are taken
Uncertainties in these estimates

V. Alternatives to the Status Quo

Supply Alternatives
- New Storage
- Reallocation of supplies
- New system interconnections
- Other

Operational changes
- Conjunctive management
- Water banking
- Long term changes in reservoir release rules
- Conditional reservoir operation and in-stream flows
- Water marketing
- Institutional changes
- Legal changes

Demand Modification
- Voluntary and mandatory use restrictions
- Pricing changes
- Public awareness
- Changes in plumbing codes
- Conservation credits
- Changes in irrigation methods
- Industrial conservation techniques
- Alternatives to water consuming activities

Drought Preparedness Study

Report Outline

Chapter

VI. Evaluation of the Alternatives

Supply Alternatives
- New Storage
- Reallocation of supplies
- New system interconnections
- Other

Operational changes
- Conjunctive management
- Water banking
- Long term changes in reservoir release rules
- Conditional reservoir operation and in-stream flows
- Water marketing
- Institutional changes
- Legal changes

Demand Modification
- Voluntary and mandatory use restrictions
- Pricing changes
- Public awareness
- Changes in plumbing codes
- Conservation credits
- Changes in irrigation methods
- Industrial conservation techniques
- Alternatives to water consuming activities

VII. Comparison of alternatives

VIII. Conclusions and Recommendations

Drought Preparedness Study

Report Outline

List of Tables

Appendix C

Drought Atlas Highlights

A DROUGHT ATLAS OF THE UNITED STATES

Prepared by

National Climatic Data Center

U.S. Geological Survey

U.S. Army Corps of Engineers

for

National Study of Water Management During Drought

Institute for Water Resources
Corps of Engineers

Ft. Belvoir, VA
1992

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Highlights of the National Drought Atlas

Maps and Graphs

I. Maps

Climatic regions of the states with overlay of physiography, rivers, principal reservoirs, principal aquifers

Areal extent of memorable droughts

Observational network used for atlas showing precipitation stations, streamflow gages, and tree ring sites

II. Graphs for each climatic region

Precipitation - graphs showing duration, area, and precipitation for median, 5-yr., 10-yr., 20-yr. and 50 yr.frequency

Palmer Hydrologic Drought Index - 5-yr., 10-yr, 20-yr. and 50 yr. frequency

Streamflow - For index stream in each region, duration vs. flow for 5-yr., 10-yr., and 20-yr. frequency, plus minimum

Regional graph showing 7-day, 10-yr. low flow relationships in cfs/sq. mi.

Tables

Numerical presentation of same data used in graphs above.

Computer Software

Floppy disks (IBM and Macintosh format)

All tables listed above, plus raw data on precipitation, Palmer index, and streamflow for period of record. Approximately 10 stations per state would be included on each high density floppy disk.

Appendix D

State Concerns

Drought Problems as report by the States

[Sources: Discussions with state-designated contacts; Western States Water Council Workshop, April 1990, and Workshop Report, July 1990]

STATE	MAJOR CONCERNS
NEW ENGLAND REGION	Not a problem over much of area; Increasing susceptibility to drought of public sector water supply and lack of redundancy of water supplies
Maine	Not a major problem; Biggest problems: agricultural damage, forest fires, and river pollution
New Hampshire	Public water supply; River water quality because of importance to tourism
Vermont	Livestock frequently affected
Massachusetts	Conflict between irrigation and municipal and industrial use; Growth versus water supply; Global warming and sea level rise
Connecticut	Domestic water supply biggest concern
Rhode Island	Lack of redundancy & inability to develop new supplies
MID-ATLANTIC REGION	Water supply for New York City area; Salt water intrusion & water supply along coast and Delaware River
New York	New York City's water supply system which is overburdened and operating currently above safe yield; Lesser water supply problems in Rochester and Syracuse areas
New Jersey	Domestic water supply is biggest concern; Salinity intrusion in Delaware River is on-going concern
Pennsylvania	Public water supplies are a major concern, especially of smaller supply systems; Agriculture
Delaware	Declines in ground water levels in confined aquifers; Salt water intrusion; Increasing municipal and industrial usage
Maryland	Drought is not a major concern because of state effort to deal with water supply; Salt water intrusion is concern in coastal areas; some areas have sufficient water but need better retrieval capability
Virginia	Southeastern coastal areas have water supply problems

STATE	MAJOR CONCERNS
SOUTH-ATLANTIC REGION	Increasing municipal and industrial use; Management of major river systems
North Carolina	Impacts to agriculture and domestic uses
South Carolina	Need for management & coordination of surface & ground water resources; Management of Savannah River reservoirs
Georgia	Many northern communities have insufficient water supply and access to recreation lakes (North relies primarily on surface water)
Florida	Competition between agricultural uses and others; Municipal and industrial use; Everglades water; Fish and wildlife; Recreation
Alabama	Droughts affect agriculture first, and then hydropower, navigation, and recreation
LOWER MISSISSIPPI BASIN	Impacts to agriculture; Mississippi River low flows (drought impacts in Mississippi-Missouri-Ohio River Basin, which drains 41% of contiguous U.S., impacts Mississippi River delta
Mississippi	1988 drought devastating to farming community; Northeastern low flows and catfish farm pumping; Northeastern Mississippi wants to "tap into" Tenn-Tom for municipal and industrial use
Arkansas	Municipal and industrial supplies, impacts to agriculture; Agricultural consumption is a major issue
Louisiana	Not a major concern; Low flows & intakes along Mississippi River & Sabine River biggest problems
OHIO RIVER BASIN	Ohio River low flows; Municipal water supplies of medium- to small-sized communities
West Virginia	Drought is not a major concern
Tennessee	Water quality and recreation impacts; Domestic supply of towns in eastern Tennessee
Kentucky	Competition of municipal water supply with irrigated agriculture
Ohio	Municipal supplies (medium-sized communities); Instream flows
Indiana	Ohio River navigation; Water supply distribution systems
UPPER GREAT LAKES/ UPPER MISSISSIPPI BASIN REGION	Mississippi River management; Missouri River mainstem management; Great Lakes impacts
Michigan	Potential impacts on Great Lakes (& diversions from); Competition between upstream and downstream users; Ground water pumping
Illinois	Navigation on the Mississippi River; Small community water supply
Missouri	Water supply in northwest Missouri
Iowa	Adequate water for sustaining life, especially southern part of state; Livestock and other agricultural impacts
Wisconsin	Agricultural and tourism impacts are of greatest concern
Minnesota	Mississippi River management and reservoir management for water supply and navigation; Minneapolis-St. Paul need alternative to Mississippi River water supply; Agriculture impacts; effluent dilution
PLAINS STATES REGION	Agricultural impacts; Management of Missouri River Mainstem reservoirs & competition for water between lake recreation & downstream uses; Small community water supplies

STATE	MAJOR CONCERNS
North Dakota	Missouri River management and planning on a basin basis; Lack of contingency water supply plans for many cities in the state; Agriculture; Tourism/recreation
South Dakota	Overall concern is reservoir use which is of value across the state, many users of Missouri River to come on-line in future; Recreation uses of Oahe reservoir - state doesn't want reservoir drawn down for downstream navigation; Hydropower; 1988 problems were forest fires and crop failures
Nebraska	1989 drought affected farmers and ranchers all across state; FERC relicensing & downstream irrigation needs; Small community M&I & aging well system; Instream flows/fish & wildlife
Kansas	Agricultural droughts are first and hardest drought on almost routine basis; Western Kansas depends on Ogallala Aquifer which faces potential depletion
SOUTHWEST REGION	Agricultural impacts
Oklahoma	Agriculture; Federal water/regulation claims; Tourism/recreation; Instream flows/fish & wildlife; Hydropower
Texas	Mostly agricultural impacts; Curtailments of all other uses for domestic & livestock uses; Irrigation & urban uses compete with recreation; Wildlife; Tourism impacts; Drought variation across state, but usually in southwest central portion; Salt water intrusion
New Mexico	Only 2 towns with chronic water supply problems (most of state relies on ground water); Major problem hampering water development is endangered species (e.g. Animas-La Plata); Agriculture
ROCKY MOUNTAIN WEST REGION	Agricultural impacts; Competition for water between agriculture and instream use; Increasing municipal water supply needs
Montana	Water shortage is persistent; Irrigators versus full stream users (especially trout fishing); Hydropower; Effluent dilution; Federal water/regulation claims
Wyoming	Agriculture; Fires
Colorado	Supply & demand issue; Agriculture; Effluent dilution; Tourism/recreation
Utah	Environmental health (drinking water) especially for small spring-dependent communities; agriculture, especially grazing; Instream flow/fish & wildlife

STATE	MAJOR CONCERNS
LOWER COLORADO RIVER BASIN/SOUTH PACIFIC COAST REGION	Increasing municipal water supply needs versus irrigation needs
Arizona	Groundwater overdraft; Drought impacts on rangeland, stock watering; Conflict between cattle & wildlife (stock ponds); Shortages on Colorado River system; Federal water/regulation claims; Instream flows/fish & wildlife
Nevada	Priorities have changed dramatically: water switched from agriculture to municipal and other competing uses, such as fisheries, wildlife habitat - increasing demand/pressure/ competition
California	People expect more water than there is; Aesthetics - recreation, streams & reservoirs; Agriculture, primarily in foothills (valleys have switched to groundwater); Fires; Municipal supplies, especially for poor planners; Salt water intrusion; Hydropower; Tourism/recreation
NORTHWEST & PACIFIC REGION	Municipal water supply needs of smaller communities; Competition between power and fish/recreation in northwest
Idaho	Anadromous fisheries; Use of Idaho stream flow for augmentation of flows downstream; Smaller communities have water supply problems; Competition between M&I and irrigation; Hydropower; Tourism/recreation
Oregon	Coastal communities affected by one dry summer because of lack of storage; Power and fish/recreation; Forest fires - resource and environmental loss; Federal water/regulation claims; Agriculture
Washington	Municipal and industrial water supply nearly maxed out in western part of state and are looking to conservation; State is concerned about wetlands; Agriculture; Hydropower; Tourism/recreation; Navigation
Alaska	Drought is not a major concern
Hawaii	Small communities have only short-term water supply; Most droughts are short-term events; Agriculture

Appendix E

Vulnerability to Drought
Corps of Engineers Divisions

New England Division
- Boston metropolitan area
- Brockton, MA
- SE New Hampshire (including Keene)
- SE Connecticut
- Rhode Island (including Providence)

North Atlantic Division
- New York City,
- Pennsylvania

South Atlantic Division
- Atlanta metropolitan area
- Raleigh-Durham-Chapel Hill, NC
- Greenville-Spartanburg, SC
- Savannah, GA
- Southern Florida
- Virgin Islands
- Puerto Rico
- (Mobile District) Small communities that depend on unregulated stream flow

Lower Mississippi Valley Division
- Navigation - St. Louis to Cairo
- New Orleans and other municipalities along Mississippi River, e.g.; Cape Girardeau, MO, Bossier City, LA

Ohio River Division
- Navigation - Ohio River
- Water quality - Kanawha River
- Lake & downstream recreation
- Towns in Kentucky River - Licking River basin (eastern Kentucky)
- Lexington-Frankfort, KY
- SW Ohio towns
- Harpeth-Franklin township

North Central Division
- Small communities, especially severe in portions of North Dakota, Iowa, & Illinois

Missouri River Division
- Upper Missouri River basin activities
- All reservoir activities (excluding flood control)
- Small towns not on reservoir or along Missouri River
- Long-term drought will impact most areas
- North Dakota, South Dakota, NW Missouri, Western, Southwestern & Northwestern Iowa
- Timing more critical than duration

Southwestern Division
- All areas of Division
- San Antonio, Corpus Christi, El Paso
- Small communities in south central, west, & panhandle Texas

South Pacific Division
- San Francisco Bay area communities
- Central Calif coast (San Jose to Santa Barbara)
- San Diego
- Salt Lake City
- Reno

North Pacific Division
- Recreation & fish migration
- Rural/small towns
- Hydropower

Appendix F

Prominent Issues Identified by Corps of Engineers Divisions

New England Division
Drought contingency planning;
ER 1110-2-1941 is inadequate - needs updating;
Funding to define role in drought management;
Need adequate Environmental Assessments;
Lack of federal perspective and policy;

North Atlantic Division
Insufficient manpower;
Difficulty in keeping a full staff representing the necessary range of expertise because of competition for those skills in the New York area;

South Atlantic Division
Techniques for evaluating social, institutional, and political impacts of water deficiencies;
Techniques for prioritizing competing demands;
Adversarial relationships among interested parties during drought emergency operations;
Lack of policy guidance on nature & extent of Corps commitment to drought emergency operations;
Public doesn't understand full water resources spectrum and authorized uses concept

Lower Mississippi Valley Division
Access to dredging equipment (dustpan dredges);
Drought indicators

Ohio River Division
Conflicts between legal directives and realities;
Excessive data requests.

North Central Division
Lake Michigan diversions
- Inability to resolve political concerns; Inability to compare benefits of diversion to negative effects on Great Lakes;

Mississippi River headwater reservoirs

Missouri River Division
Political pressures from states and within Corps;
Problems with Corps drought policy and authorities;
Long-term vs short-term impacts;
"Data is problem, not techniques"

Southwestern Division
Techniques for integrating economic, environmental, social, institutional, & political considerations into drought management decisions;
Absence of mechanism for resolving intergovernmental differences on drought management priorities;
Convincing locals that Corps is last resort for emergency water assistance;

South Pacific Division
Agency coordination
Lack of drought contingency plans

North Pacific Division
Fisheries-related issues
- Techniques for relating minimum low flows to biological consequences
- Political/institutional problems associated with fishery management
- Prioritizing competing demands

Lack of clear policy guidance on use of PL 84-99

Appendix G

Draft Report Review Comments
Summary

Corps of Engineers

North Pacific Division

They concur that a water control plan should include the entire continuum, and further suggest that there should be but one comprehensive database system and one comprehensive water management model for use by all agencies for decision-making on how to operate the systems in the continuum.

South Pacific Division

The Atlas is an essential tool if the Corps is to make plans based upon possible projections.

North Atlantic Division

Comments from districts are provided.

North Central Division

The Division wanted more discussion of Great Lakes navigation and legal impediments/study restrictions regarding Lake Michigan diversions. They also want more discussion of Corps Drought Contingency Planning and differences between the proposed DPS and the Corps contingency plans.

South Atlantic Division

Comments were incorporated.

Southwestern Division

SWD agrees with the report recommendations.

Missouri River Division

No comments.

New England Division

Many specific comments are provided, many of them questioning reasoning. They don't disagree with the report recommendation, rather, they want a better linkage to the problems. They want the report to indicate how the drought preparedness studies will deal with drought mitigation efforts such as crop subsidies, relief payments, and forest fire management.

Lower Mississippi Valley Division

Concurs with the conclusions and recommendations and provides specific comments, mostly dealing with Mississippi River navigation. The drought atlas should include a public information section for drought safety.

Fort Worth District

The Ft. Worth DCP's may provide useful information for the proposed Drought Preparedness Studies.

Little Rock District

The proposed Section 308 would hurt the Corps' ability to respond to drought.

Walla Walla District

Information about ongoing activities in Walla Walla which might be included in the report are provided.

Norfolk District

Commented that a number of states have instituted water efficiency standards for new construction.

Huntington District

No recommendations for change.

Baltimore District

Recreation discussion should be expanded to include economic impact of recreation losses on the local economy. Also, discussions of new environmental mission and fish and wildlife prioritization should be included.

Nashville District

No comments.

Vicksburg District

No comments.

Savannah District

Several suggestions for the Drought Atlas were presented.

Jacksonville District

Positive effects of drought on the environment should be included in the study, if possible. They believe that water managers need more and better data to make decisions (because of strong competition for water in light of limited availability during drought), which needs to be stressed in the conclusions.

Tulsa District

No comments.

San Francisco District

The Draft Report relies too much on the Corps perspectives. They recommend discussing USGS's data acquisition and research efforts, among other suggestions.

St. Paul District

The DPS recommendation is a logical approach. The Headwater Draft Low Flow Review Report may be useful to IWR as a case study.

Memphis District

The comments specific to south Louisiana's problems are provided.

Corps Headquarters

Planning, Central Branch

A stronger connection should be made between the defined problems and the actions recommended. Can addressing these problems make a difference? The usefulness of the Atlas will be diminished if no design for keeping it current.

Armor, Public Affairs

The study needs a Public affairs plan as well as one for each DPS, so as to keep new media and the general public informed. A public affairs plan should allow for public interest groups to make statements on the record during the DPS's.

Hydrologic Engineering Center

Good overview from the national perspective, but the report doesn't pay sufficient attention to the capability of the Corps to service water needs during drought. The first year report should recommend that each Corps reservoir be analyzed to improve its operation during drought.

Federal Agencies

ICPRB Interstate Commission on the Potomac River Basin, Roland Steiner

Several comments offered to aid portrayal of the Potomac River Basin studies history.

Office of Env & Energy, HUD, Richard Broun

"Efforts should be concentrated at the national level, and response capabilities at the state and regional levels."

Intl. Boundary & Water Comm., Conrad Keyes

Textual corrections for completeness and accuracy.

St. Lawrence Seaway Dev. Corp., Stephen C. Hung

Textual corrections for accuracy.

Water Res Div, TVA, Ralph H. Brooks

Report present good national perspective on water management during drought and provides useful information. Specific comments and information about TVA are provided to aid report. They recommend other reservoir management agencies (e.g., Bureau and TVA) be considered as DPS sites. The TVA has demonstrated many successful approaches to various concerns with river basin management, especially drought management approaches. The National Drought Atlas include streamflow information on regulated rivers, based on information from reservoir owner-operators, especially focusing on shorter-term variations, e.g., 1- and 2-day flows.

Power Resources Div., SEPA, Jim B. Lloyd, P.E.

Several terminology revisions are provided.

Office of Protected Res, NMFS, Nancy Foster, Ph.D.

Comment about NMFS role in the EIS process.

Off Policy Analysis, EPA, Daniel Fiorino

Report underestimates broad ecological effects of drought on streams and wetlands, as well as instream water quality; the report does not adequately address EPA authorities; the third recommendation does not go far enough to deal with the conclusion that no consensus currently exists within the water management community on a national strategy; and that the report is not clear on how water management overview relates to the question of drought. He offers to assist us in looking at the broader ecological drought effects in the report, in the overall study, and in the upcoming regional drought studies. He also urges our study to incorporate planning for climate change in at least one of the regional studies, and include climate change impacts as part of the national atlas. He suggests that we initiate a more formal exploration of interagency coordination, and a dialogue among federal agencies, in addition to more studies.

Chief Hydrologist, USGS, Philip Cohen

Several pages of editorial comments are provided, especially concerning the U.S. Water Resources Council and USGS data acquisition. The USGS and other agencies have developed regional techniques for estimating drought statistics at ungaged sites, although these regional techniques need to be improved so that better predictive methods are available to water managers.

Adapt Br, Clim Change Div, EPA, Joel B. Smith

The DPS and Atlas should prove very useful in future drought planning. Attempts should be made to incorporate climate change aspects into drought planning and the DPSs. The atlas should include modified historic climate data (by imposing climate change scenarios).

Commander, USCG, Actg Ch, Short Range Aids to Navig. Div., T.J. Meyers

No comments.

National Weather Service, Elbert W. Friday, Jr.

The National Drought Atlas is an important effort. Comments on the data acquisition and research, technical tools, and data inadequacies section are provided. The knowledge of site/area conditions is important in forecasting.

Environmental Review, Bureau of Reclamation, Beth Ward

Comments include corrections/modification on Mexican Water Treaty of 1944, basis for Bureau within Federal powers, limits on operations freedom with respect to water rights and authorizations, etc., and several other comments/suggested revisions.

States

Arkansas Soil & Water Cons. Com, Jon Sweeney

The DPS will need input from state level managers to succeed.

Delaware DNR & Environmental Control, A.J. Farling, Administ.

DPSs and legal/organizational studies would be most effective in coordinating efforts to improve technical information and are not appropriate for development of local response plans. The Atlas should add groundwater. Delaware has not been faced with the reported obstacles, and is fairly well positioned. Delaware has needs in the area of implementation and assistance for smaller towns.

Wisconsin Dpt Agr, Trade & Consumer Prot, Alan T. Tracy

The conclusions and recommendations appear warranted and reasonable. The report should better define whatever regions are used or referred to.

Montana Water Res Div, Gary Fritz

A few specific comments are provided. The state believes the best place to put responsibility for water allocation decisions during drought is at the most-local level consistent with the extent of the drought. The role of government agencies is to manage water in conformance with the people's decisions (priorities for scarce water allocation set at local level). The Corps Missouri River Master Manual review would be a good case for study.

Wyoming State Engineer, Gordon W. Fassett

The lack of good forecasting techniques regarding drought severity and duration, and that recommendations for the continuing improvement of forecasting models should result from this drought study. Additional attention needs to be given to the western states where Corps management has been secondary to that of the Bureau of Reclamation.

Georgia Water Resources Mngmnt Br, Nolton G. Johnson, P.E.

Georgia has initiated drought planning efforts (the report does not include Georgia as a state with a DCP).

Missouri Director, Water Resource Progr, Steve McIntosh

At the National Drought Management and Planning Conference (Denver 1990), people from across the nation agreed with the importance of the study's conclusions. He hopes that the study will solve some of the problems associated with crossing political and organization boundaries.

Interst Compcts Coord, Water Rights & Use Div, Tex. Water Comm., Robert M. Johnson

The Commission generally agrees with conclusions and recommendations, but some sections lack consideration of state viewpoints. Many comments are provided.

Universities

The University of Texas, Austin, David Maidment

Texas intends to reissue its water plan every 1 to 2 years, rather than every 5. Discussion of a pilot study in Tarrant County area in Fort Worth, where expert system would define how law/infrastructure limit water transfers.

Regional Water Agencies

South Florida Water Management District, Stephen S. Light

The District provided detailed comments for review and incorporation in the formal District response. Their primary concerns is that much of the report's discussion is not directly applicable to South Florida's water shortage problems, and further, some sections indicate a lack of understanding of their water management concerns and practices. An adequate linkage between water management during drought and long-term water multi-objective water management has not been made.

Others

Bracken and Baram (law firm), Massachusetts, Michael Baram

The report carefully presents a vast range of issues and research subject of importance. Four more water conservation issues deserve consideration based on his experiences with DOI, DOE and Massachusetts.

Pacific Water & Power, Inc., Robert R. Doelle

PWP has previously investigated drought problems in California to a significant degree of understanding, being able to objectively assess the drought problem without any political or vested interest influence. They present a background on existing Congressional California Legislative Policy and Intent, then comments and makes recommendations. Basically, they believe it is only necessary to implement alternative and demonstrated water resource technology through the private sector so as to allow a "free market economy" to evolve in water and power. The ways and means already exist to resolve water management policies.

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This is a report of the first year of the National Study of Water Management During Drought. The Corps of Engineers began the study after the severe droughts of 1988. The primary objective of the study is to find strategies to improve water management during droughts in the United States. The report explains how and why water is managed the way it is now, lists the impacts of drought, the problems in the current water management systems, and the roadblocks to change for the better. It cites some examples of change which have been successful, then draws conclusions about the state of the water management as it is now, and the advancements that can reasonably be expected. Finally, it lists three recommendations which will be pursued in the remainder of the study. Those recommendations constitute the strategies for improving water management during drought.

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