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U.S. ARMY CORPS OF ENGINEERS
INSTITUTE FOR WATER RESOURCES

MANAGING WATER FOR DROUGHT

NATIONAL STUDY OF WATER MANAGEMENT DURING DROUGHT
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MANAGING WATER FOR DROUGHT

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NATIONAL STUDY OF WATER MANAGEMENT DURING DROUGHT

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Findings of the National Drought Study

The nature of drought

1. **Definition.** Droughts are periods of time when natural or managed water systems do not provide enough water to meet established human and environmental uses because of natural shortfalls in precipitation or streamflow.

2. **Drought management is a subset of water supply planning.** The distinction between a "drought" problem and a "water supply" problem is essentially defined by the nature of the best *solution*. Urban areas that persistently use more than the safe yield of their water supply systems may have frequent or even standing drought declarations that could only be eliminated through strategic water supply measures. Those measures can be structural, such as the construction of new reservoirs, or non-structural, such as conservation.

3. **Drought response problems are water management problems.** Participants at a National Science Foundation Drought Workshop concluded that attempts to understand and address the failings of water management during drought would be unsuccessful unless shortcomings in the larger context of water management are also understood and addressed. This was also one of the conclusions drawn by the Corps of Engineers in the first year of the National Drought Study (IWR, 91-NDS-1), and the premise upon which the DPS method was built.

The seriousness of the problem

4. **Concern is widespread.** Fifty percent of all **water supply** utilities asked their customers to reduce consumption during the 1988 drought (Moreau, 1989). In a 1990 poll, forty-one percent of U.S. mayors anticipated water shortages in the next several years, caused by drought, growing population, water pollution, and leaks from distribution lines (Conserv90).

5. **Water use is stable nationally.** Several reports in the 1970s forecast rapid increases in American water use, creating an impression that lingers to this day that water use *is* increasing. But the National Council on Public Works Improvement reviewed several nationwide studies and concluded that each "faced several problems in developing a comprehensive and reliable estimate" of future water supply needs. In fact, total American water use is less now than it was in 1980, although there is growth and more intense competition for water in some regions.

6. Several states reported that **water quality** suffered during drought because low flows affected their ability to dilute effluents from wastewater treatment plants and sustain the aquatic ecosystem.

7. **Drought impacts are difficult to measure.** This is because:

- They are often reported as reductions from the benefits a water system can support when water is plentiful; this approach often overstates the problem because these drought "costs" are usually based on sizing the water system so as to maximize return on the economic and environmental investments in the water system and is not necessarily based on efficient use of the water resource.

- Impacts caused by drought are difficult to separate from impacts that occur coincidentally during a drought. Because droughts continue for much longer than floods, earthquakes, or wind storms, external factors (such as recessions, market changes, land management, and fishing practices) may also contribute to the impacts associated with drought, as was the case recently in California.

- Regional drought impacts are often more than offset at the national level by gains in production somewhere else in the country.

8. **Drought impacts understate our aversion to droughts.** Despite the overestimation of impacts induced by the above factors, the level of conflict and anxiety droughts stimulate is still apt to be far greater than the magnitude of impacts would suggest. On a national and even a state level, the impacts to agriculture and urban areas from the California drought were relatively small, but the drought was newsworthy for years and played a significant role in the passage of new state and new federal laws. Observations of droughts in the 1980's suggest that turmoil will be greater when the losses are felt more personally and when long term entitlements to water use are threatened.

Shortcomings in the way we have dealt with droughts

9. **Learning from the past**. Lessons learned during ongoing droughts are too rarely documented, critically analyzed, and shared with other regions;

10. **Price and efficient use.** Water is almost always priced below its economic value to users or full cost to produce. This tends to impede efficient use of water.

11. **Assessing risk.** Information about expected drought severity and duration is not readily available, so risk assessments cannot be quantified as well.

12. **The problems are integrated, solutions are not**. Management responsibilities for problems that are physically integrated in a river basin are fragmented by agency missions and political boundaries. The many disciplines required to analyze drought problems and develop and institute solutions are poorly coordinated.

13. **Typical problems with traditional drought plans** include (IWR, 91-NDS-1):

- they may not recognize newer uses of water

- they are usually designed for the drought of record, without consideration of the rarity of that drought

- they often are not understood or endorsed by those who will suffer the impacts of the drought

- they may not sufficiently address equity issues or economic differences in the use of water

- they are often triggered by indicators not related in a known way to impacts.

- they are better characterized as documents rather than ways of behaving, and so their effectiveness diminishes as staff changes occur and time passes between plan preparation and drought.

14. **There are three time frames for response planning.** Drought responses can be classified as strategic, tactical, and emergency measures. *Strategic* measures are long term physical and institutional responses such as water supply structures, water law, and plumbing codes. *Tactical* measures, like water rationing, are developed in advance to respond to expected short term water deficits. *Emergency* measures are implemented as an *ad hoc* response to conditions that are too specific or rare to warrant the development of standing plans.

15. **Technology transfer.** Methods for managing water for multiple objectives have been developed and tested over decades, but that tradition resides in the agencies that built the extensive complex of federal dams, not in the organizations responsible for preparing tactical drought plans. This expertise must be transferred before that institutional memory is retired.

16. **Law and drought**. Law sometimes drives and sometimes constrains water management during drought. Basic appropriations doctrine discourages water conservation, because water not put to beneficial use may be lost, but many western states have modified the basic doctrine to accommodate conservation. In addition, sixteen eastern states have legislation recognizing the need to conserve water supplies.

17. **Basin transfers and drought**. Diversions are strategic measures designed to increase water supply reliability. During a severe drought, if the necessary facilities exist and the state law allows, temporary interbasin diversions may be authorized to meet the needs of the most severely affected areas.

Lessons from the Case Studies

18. **Domestic water users are willing and able to curtail water use during a drought.** During the first two years of the drought, a mixture of voluntary and mandatory conservation in California's cities reduced water use from 10 to 25%. In the last three years of the drought, urban conservation efforts were generally more intense. Similar savings were recorded in Seattle and Tacoma, Washington in their 1992 drought.

19. **Investments in infrastructure can increase the options for adaptive behavior.** Water banking, storage for instream flow maintenance, conjunctive use of groundwater and surface water, regional interdependence, and economies of scale require a water storage, allocation and distribution system. California's storage and distribution system provided the flexibility and resiliency to withstand severe droughts, even in the face of rapidly growing population and increasing urban and environmental demands on a fixed supply of water.

20. **Droughts act as catalysts for change.** Complex sociopolitical systems, which reflect a multitude of competing and conflicting needs, are not particularly well suited for crisis management. Yet despite these well understood and accepted deficiencies in the democratic decision making process, the overall conclusion is that communities not only weathered the drought in a reasonably organized manner, but also introduced a series of useful water management reforms and innovations that will influence future water uses in a positive manner.

21. **Conservation may or may not reduce drought vulnerability**. To the extent that methods of reducing water use during droughts, such as discouragement of outdoor use and physical modifications to toilets and faucets to reduce water use, are used as long term water conservation measures that allow the addition of new customers to a water supply system, drought vulnerability is increased. When normal use becomes more efficient, efficiency gains are harder to realize during a drought. But it is not always that simple. In the Boston Metropolitan area, for example, long term conservation will reduce drought vulnerability because some of the water saved will also be stored for use during droughts and because some of the most effective long term conservation savings (such as the detection and repair of leaks) cannot be implemented quickly enough to be as effective as a drought response.

The DPS Method

22. **The lineage of the DPS method.** The DPS method is derived from the traditional strategic water resources planning framework, but addresses two common shortcomings in water management: the separation between stakeholders and the problem solving process, and the subdivision of natural resources management by political boundaries and limited agency missions.

23. **Drought responses are primarily behavioral.** The DPS method reflects the fact that, like responses to earthquakes and fires, drought responses are largely behavioral, and their success depends on people understanding their role, and knowing how their actions fit into a larger response.

24. **Collaboration between agencies and stakeholders can make planning much more effective.** This collaborative approach:

- harnesses the knowledge and creativity of stakeholders near the beginning of problem solving efforts;
- makes it more likely that stakeholders can take actions unilaterally to reduce their drought vulnerability;
- builds broader, deeper stakeholder support for water management plans.

25. **Lessons learned from past efforts at collaborative planning are abundant and must be heeded.** The benefits of participatory planning are not guaranteed by simply making the planning process accessible. There is a substantial body of research and practical experience with participatory planning, especially in water resources, that is often overlooked. The temptation is to believe that honesty and common sense will suffice. The participatory methods used and developed during the Drought Study recognized and managed these potential liabilities:

- public involvement can involve considerable expense.
- the “public” that gets involved in planning may be self-selected and unrepresentative of the public that will be affected by drought.
- if the public is actually involved in the study process (as opposed to just expressing problems and goals in workshops or surveys), then additional efforts may be required to provide technical training and to coordinate the work of public task forces.

- the misapplication of the techniques of group process can result in the use of stakeholder opinions on issues that should be addressed by experts.

- broader citizen participation increases the risk that the planning process will be slowed or stopped.

26. **The problem solving team should be appropriate to the problem set.** Rarely will there be one agency or political entity whose responsibilities include all the problems a region will face during future droughts. The creation of the DPS team, then, is the creation of a new entity whose collective interests and responsibilities are pertinent to the set of problems addressed. Thus, the DPS team constitutes a new, integrated community that more closely reflects the integrated nature of the problemshed.

27. **The objectives for the drought response must be articulated early and clearly.** The DPS method uses 5 management parameters including the ***criteria*** decision makers will use in approving or rejecting new plans, ***planning objectives***, ***constraints***, ***measures of performance***, and environmental, economic, and social ***effects***. Developing good planning objectives early is paradoxically the most important and most often ignored step in the drought planning process.

28. **Innovations**. The DPS method takes advantage of several innovations developed in parallel during the National Drought Study:

- The shared vision model (see Finding 29)
- Circles of influence and decision maker interviews
- Water Conservation Management
- Trigger Planning
- The National Drought Atlas
- Virtual Drought Exercises

29. **Shared vision models** are computer simulation models of water systems built, reviewed, and tested collaboratively with all stakeholders. The models represent not only the water infrastructure and operation, but the most important effects of that system on society and the environment. Shared vision models take advantage of new, user-friendly, graphical simulation software to bridge the gap between specialized water models and the human decision making processes. Shared vision models helped DPS team members overcome differences in backgrounds, values, and agency traditions.

30. **A Virtual Drought Exercise** is a realistic simulation of a drought using the shared vision model to simulate that experience without the risk associated with real droughts. Virtual Drought Exercises can be used to exercise, refine and test plans, train new staff, and update plans to reflect new information.

31. The **National Drought Atlas** (IWR, 94-NDS-4) is a compendium of statistical information designed to help water managers and planners answer questions about the expected frequency,

duration and severity of droughts. The Atlas provides a national reference for precipitation and streamflow statistics that will help planners and manage assess the risks involved in alternative management strategies.

32. **Water conservation management** is the prioritization and selection of water conservation measures based on their estimated benefits and costs. A new version of a widely used water use forecasting model, IWR-MAIN, provides a powerful new tool for linking water savings with specific combinations of water savings measures.

33. **Trigger Planning** is a collaborative and continuous process for updating water supply needs assessments and responding in time, but just in time, with the necessary economic and environmental investments necessary to address those needs. Trigger planning uses a shared vision model and the DPS method to minimize those investments while reducing the frequency of drought declarations caused by inadequate water supply. Trigger planning was tested and refined in the Boston metropolitan area.

34. **There are simple ways to improve agency collaboration with elected officials and stakeholders**. The DPS method used "circles of influence" to effectively and efficiently involve stakeholders in the development of plans. The circles created new ways for people to interrelate and interact, without destroying the old institutions, their responsibilities or advantages. In addition, during the DPS's, political scientists conducted interviews with elected officials and other influential political agents. The interviews were included in reports available to the entire study team, and were used to assure the planning process addressed issues critical to the public and elected officials.

NATIONAL DROUGHT STUDY

ACKNOWLEDGEMENTS

This guidebook was produced as part of the National Study of Water Management During Drought, which was managed by the Institute for Water Resources (IWR) of the U.S. Army Corps of Engineers. The guidebook is based on the experiences, research, and critical analysis of the over one hundred professionals who worked directly on the National Drought Study, and the many others who criticized and improved the case studies in which these methods were tested.

The principal authors of this report are Mr. William Werick, the National Drought Study manager, and Brigadier General (Ret.) William Whipple, Jr. Material contained in the annexes was also provided by Dr. Hanna Cortner, Ms. Allison Keyes, Mr. Charles Lancaster, Dr. Merle Lefkoff, Dr. William Lord, Dr. Richard Palmer, Mr. Van Dyke Polhemus, Dr. Robert Waldman, Dr. Gene Willeke, and Dr. Charles Yoe.

The ideas presented in the report owe much to the work of Dr. Eugene Z. Stakhiv, Chief of IWR's Policy and Special Studies Division. Dr. Stakhiv had made the case in previous papers that federal planning principles were unique in that they constituted a *comprehensive* set of principles for water resources planning and management that had been established and tested in an unprecedented coalition of researchers and practioners. Moreover he demonstrated that they could be used to address regional objectives. Under his direction, the National Drought Study developed these concepts one step further, applying these principles to what were primarily *regional* and *operational* water resources matters.

Mr. Zoltan Montvai, of the Corps' Headquarters Planning Directorate, oversaw the National Drought Study from its inception to its final products. He assiduously reviewed and offered advice on making this report (and others) understandable and responsive to users' real needs. The Director of Planning for the Corps is Dr. G. Edward Dickey.

Dr. Richard Palmer's contribution to this study was inestimable. Without him, there would be no *shared vision models*, and the systemic planning process we present here, no matter how sound, would be more difficult to use, and thus, less effective. His scholarship, enthusiasm, and inventiveness motivated the rest of the Drought Study team. The intellectual influence and experience of General Whipple, Dr. Bill Lord, and Dr. Gene Willeke are reflected in diffuse and numerous ways in this report. David Getches offered review and counsel at critical junctures, but even more importantly inspired the Drought Study team and others with his leadership of the Park City Workshops sponsored by the Western Governors Association and the Western States Water Council. Dr. Robert Brumbaugh, Dr. Gene Willeke, Ms. Germaine Hofbauer, and Mr. Gene Lilly have formed the central core of the drought study team over the years.

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The report, of course, is a product of the National Drought Study. The report on the first year of the study (NDS-1) acknowledges the many professionals who set the course and collaborative tone for the study. Of those, however, three people deserve to be acknowledged again since they shaped the study in its infancy. Harry Kitch (Headquarters, U.S. Army Corps of Engineers), Randy Hanchey and Kyle Schilling (past and current directors of IWR) shaped the basic study direction, making sure the scope and subject matter of the study would include non-Corps and non-federal problems and viewpoints.

William J. Werick
Study Manager

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FOREWORD

Damaging, prolonged droughts in various parts of the country in the 1980's and ’90’s have been disruptive to normal living patterns. Experience has shown that although many states and federal agencies possess drought contingency plans, these plans are not as effective as they should be; droughts still cause substantial turmoil. In response to the Droughts of 1988, Congress authorized the Corps of Engineers to make a nationwide survey of this situation, with the goal of finding a better way to manage water during drought. This effort was titled the National Study of Water Management During Drought. This report represents the collaborative work of over 100 researchers and practioners whose model approach to water management during drought was tested and refined in several case studies across the country.

The approach is derived from general water resources planning and management principles, but has been broadened to accommodate the non-structural, regional centered nature of drought management. Because of this, the approach can be used for water resources issues beyond just droughts.

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INTRODUCTION

This report summarizes the method of improving water management during drought developed during the four year National Study of Water Management During Drought. The method was tested and refined in four field studies in different parts of the country, in which teams of water managers and users worked together to reduce drought impacts. In each case, the situations are complex, involving many different uses of water. Because such important state and local responsibilities are involved, only a joint cooperative approach between state and federal agencies could provide satisfactory answers. These cooperative field studies were called "Drought Preparedness Studies" (DPS) and the approach, the "DPS method."

A DPS can develop the best means of minimizing adverse impacts of drought situations with existing infrastructure and institutions. However, in many cases, the best management of existing facilities and institutions could still result in unacceptably destructive impacts during a severe drought, particularly as water demand increases with future population growth. In such cases, the DPS approach can identify the need for and begin the process of developing agreement on the long-range water resources actions necessary to increase the capacity of the region to withstand drought. Such actions should include full consideration of many alternatives, such as conjunctive use of ground and surface water, inter-system management coordination, other means of achieving water quality, long range demand management, and even new or enlarged reservoirs.

Many components of the DPS approach are time-proven methods and ideas derived from federal water planning experience and research, modified to reflect the importance of non-federal, non-structural responses to droughts. The most visible innovation of the National Drought Study is the use of stakeholders collaboratively built "shared vision (computer) models" of their water management environments. The DPS method also encourages the use of alternative dispute resolution techniques and new statistical methods that can provide additional information on the expected severity and frequency of droughts. What is most significant is that all of this has been integrated into a uniform, consistent approach that has been tested and shown to work.

The purpose of this report is to explain the procedure for cooperative federal-state Drought Preparedness Studies, to indicate how these studies relate to the longstanding principles and guidance for federal water resources investigations, and to indicate the means of implementing conclusions arrived at in any given region. Certain parts of this report will be useful to municipalities and other entities engaged in drought planning within the scope of their own responsibilities. However, the more important use is in dealing with problems which overlap jurisdictions.

THE LARGER CONTEXT FOR WATER MANAGEMENT DURING DROUGHT

Most communities that suffered impacts from the droughts of the 1980's said they could have been better prepared, including those communities that had prepared contingency plans which specified how the operations of water systems should change during a drought.

Federal water management agencies have established sound principles and guidelines applicable to water resources studies. However, these principles have not been widely applied to plans for water management during drought. This is because so much of the responsibility for actions to deal with drought rests in the states and municipalities rather than in the federal agencies. The National Drought Study team developed and tested a method for developing drought contingency plans which takes advantage of federal background and expertise. This guide explains how a region can develop practical drought preparedness plans using those methods, while maintaining the flexibility needed for local, non-federal decision making.

WHO SHOULD USE THIS GUIDE?

This guide can be used by anyone concerned about reducing the vulnerability of a water system to drought impacts. It is meant mainly for regional problems, from quick reviews of drought vulnerability to long and involved preparedness efforts. The method is suitable for:

- federal and non-federal drought preparedness planning
- water systems operation during drought
- regulatory permitting related to drought management

The DPS method may also be useful in dealing with *emergency* water shortages, such as those caused by infrastructure problems or system contamination. The DPS method is based on long term water planning principles, so it can be applied quite naturally to both federal feasibility studies and non-federal water supply planning.

HOW SHOULD THIS GUIDE BE USED?

The **main body** of this guide explains a drought preparedness process in seven sequential, iterative steps. None of the steps should be skipped, but the amount of time and money spent on each step depends on the particular situation in a region and how much information is already available.

The **annexes** to this report address the most common issues raised during the case studies in each of several professional areas. The annexes are not meant to be summaries of these subjects, but in some cases (such as the annex on alternative dispute resolution) a brief overview of the subject was also provided.

WHEN SHOULD THE DPS METHOD BE USED?

There are five characteristic situations which call for the use of this method:

- **If you just don't know whether your community or your region is well prepared for a severe drought.** It is unusual for one person to be responsible for regional drought preparedness, so it may be necessary to ask several people if (and why) they are confident that the region is well prepared. This guide can be used to develop an inexpensive preliminary estimate of drought vulnerability.

- **If you know there is a drought plan, but you don't know if it is adequate.** Only a little more than half the states have drought preparedness plans. About half of the country's urban water suppliers have drought contingency plans, but in 1988, fewer than 30% of the urban water utilities had any kind of quantitative data to support decision making during droughts. In many cases, the plans were based on little research and unrealistic expectations of consumer responses.

- **If you are in the process of developing a drought preparedness plan.** It has become more commonplace to require drought plans for utilities and reservoirs. The regulations often require a *document* which lists the curtailment actions that will be taken when *drought indicators* reach certain values, the water savings expected from these actions, and the *coordination* with agencies that would be initiated. These sorts of "plans" offer some benefit and typically require a minimum of public process and staff time. The disadvantages of these plans is that they typically do not establish the real objectives for water management, nor do they compare alternative drought plans to find the plan that best addresses those objectives. The lack of public process may mean that water users (especially new users such as recreators) will be less well prepared and more adversarial when the drought occurs.

- **If you are involved in any water resources planning or in the resolution of water resources conflicts, or**

- **If you have been faced with a drought which raised concerns about the adequacy of future water supply.** The methods of the National Drought Study are based on water resources management principles, so most of what is written in this report is applicable to the rest of the hydrologic spectrum and to strategic planning.

WHAT ARE THESE METHODS BASED ON?

The methods described in this guide are based on longstanding, well accepted water resources planning principles, updated and tested in the **National Study of Water Management During Drought** (1990-1993), a study led by the U.S. Army Corps of Engineers. The study team consisted of more than one hundred water managers, or consultants, and researchers from the Corps and other federal and state agencies, leading universities, cities, consultants, private industries, and environmental groups. The methods described in this guide were tested and refined in several case studies representing many of the conditions across the U.S. A brief comparison of the DPS method to traditional ways of responding to drought is provided in Chapter 2.

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1 WATER MANAGEMENT AND DROUGHT

The real need is to institutionalize drought management into improved overall *<u>water management</u>* *systems*

- Conclusions from a National Science Foundation Drought Water Management Workshop, February 1990 (NSF, 1990)

The NSF workshop participants concluded that attempts to understand and address drought problems will be unsuccessful unless the larger context of which they were an inseparable part is also understood and addressed. This was also one of the conclusions drawn by the Corps of Engineers in the first year of the National Drought Study (NDS-1), and the premise upon which the DPS method was built. This chapter provides a conceptual structure for understanding the whole into which water management during drought fits, and briefly illustrates linkages between water management issues.

THE MEANING OF THE WORD "DROUGHT"

There are many definitions of drought. The National Drought Study team sought a definition that was consistent with historic scholarly usage and accepted usage in water management operations so that water managers and planners perceptions of this phenomenon could be integrated.

A community is often asked to make sacrifices while a drought continues, and so differences in the operational definition change the answers to important, practical questions such as, "should we begin to sacrifice now?" and "can we stop sacrificing now?" The next few paragraphs show the range of meanings "drought" can have, and then suggests a basis for creating a definition which can be used in regional planning.

There are at least 10 meteorological, 4 agricultural, 3 hydrologic, and 3 socioeconomic definitions of drought used in water management literature (NDS-3). Some authors restrict its use to what others call meteorological drought (less precipitation than usual, with "less" sometimes quantified). Others use "drought" to refer to *agricultural* drought (not enough precipitation for crops), or *hydrologic* drought (less water available than usual, typically defined statistically in terms of less than normal streamflow). But in water systems that use distant sources of water or large reservoirs, declarations of drought may be unrelated to the amount of local rainfall. Because this is a guide to managing water to *reduce impacts* from "drought", the definition used to guide the development of the DPS approach had to include social and economic considerations, as well as the meteorological. In many cases, the connection between meteorological and socioeconomic droughts is obvious. The definition also had to be meaningful to water supply managers and water system operators. Finally, there are also some types of water shortages that are not called "droughts." For example, although many of the planning procedures might be the same, most water managers agree that a pipe break or an oil spill, either of which can cause a severe water deficit, should not be called a "drought." Thus, for the purposes of this text, ***droughts are periods of time when natural or managed water systems do not provide enough water to meet established human and environmental uses because of natural shortfalls in precipitation or streamflow***.

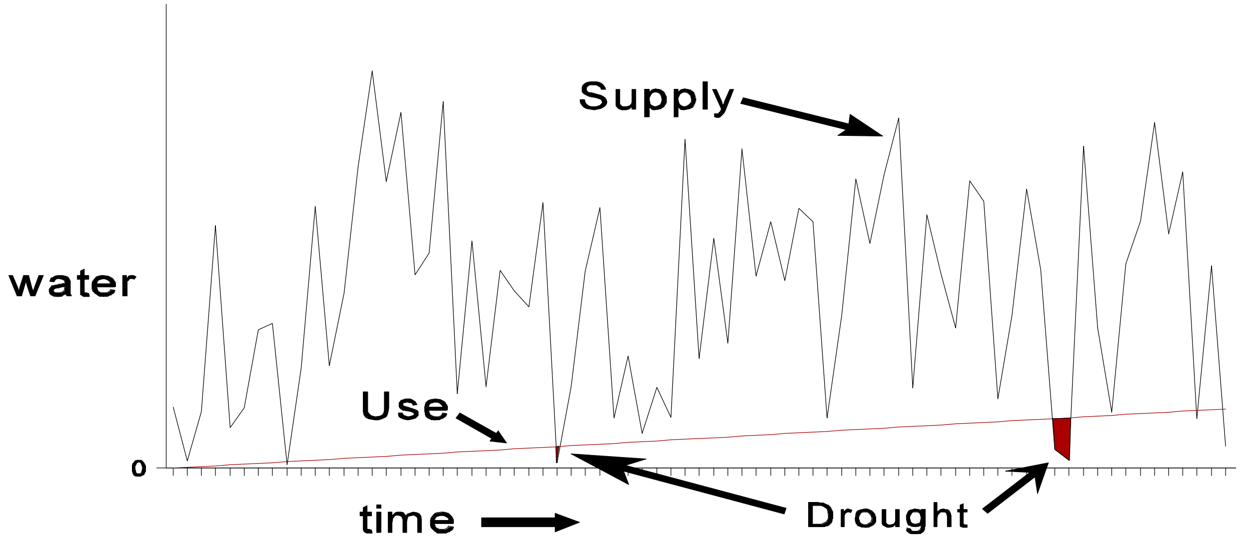
A WATER RESOURCES PLANNER'S VIEW OF DROUGHT

If a system is said to have a safe yield of 300 million gallons of water a day at 98% reliability, it means that it can supply 300 million gallons per day (mgd) 98% of the time. The other 2% of the time, the water manager will declare a drought and make management adjustments until supplies return to normal. Water supply planners can make adjustments so that drought impacts will be less severe and less frequent over time.

Water supply planners accept residual risks of very infrequent droughts because the environmental, social, or economic costs required to completely eliminate those risks is too great.

Over the last several decades, water resources planning has become more sophisticated in response to greater public concern about the environment, recreation, and the integrity and effectiveness of government. Consequently, more sophisticated procedures for estimating impacts, evaluating alternatives, listening to and informing the public, and making tradeoffs among dissimilar impacts have been developed and tested. Much of this work is captured in the series of summary reports on federal water resources planning and evaluation: Proposed Practices for Economic Analysis of River Basin Projects (May 1950, revised in May 1958 and referred to as "The

FIGURE 1. A GRAPHIC DEFINITION OF *DROUGHT*



Green Book"), Senate Document 97 (1962), Principles and Standards for Planning Water and Related Land Resources (the P&S) (1973) and Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies (the P&G) (1983). (See Annex A for a discussion of these reports).

Figure 1 represents water use as a single line, suggesting that if a new reservoir were built, increasing supply, the frequency and severity of future drought impacts would be reduced. In practice, however, new reservoirs often bring new recreational uses that become firmly established when precipitation and streamflow are normal. When a drought does occur, planners may find that those who have a stake in lake recreation will resist drawing the reservoir down. The new uses bring new benefits, but add to the complexity of drought response.

A WATER *MANAGER'S* VIEW OF DROUGHT

The definition of drought for short-term management is consistent with the written definition on page 6 and Figure 1, but more concrete. It can be more precise because current stores of surface and groundwater and current use patterns can be determined fairly accurately. It must be more specific because coordinated responses to drought require a common view of whether the region is in a drought, how bad the drought is, and how long it is likely to last. Initiating drought responses too early, too late, or unnecessarily can be costly. Because an official drought declaration may be necessary to initiate some response measures, water managers typically declare the time the drought started and ended.

Integration. A simple and meaningful criticism of most plans for drought response is that they do not resemble real responses to droughts; the furor caused by droughts is rarely foreshadowed in drought planning (NDS-1, NDS-5).

When a drought occurs, water managers will face the same question planners addressed in the design of the water system: which plan produces the most desirable level and allocation of beneficial effects?
Like the long term planner, the real time manager will have to listen to and inform the public, deal with other governments, agencies, and private organizations, and confront criticism. And like the planner, the manager will deal with risk and uncertainty surrounding the consequences of any proposed action.

A principal finding of the National Drought Study was that as a rule, water management during drought has not benefited much from the research, development and testing that has improved *strategic* water resources planning over the past four decades, despite the fact that practioners in both fields try to assure efficiency and equity in the allocation and use of water and related land resources.

THE RULES FOR MAKING DECISIONS, INCLUDING DECISIONS ABOUT WATER MANAGEMENT DURING DROUGHT

Simplifying assumptions make it easier to deal with things in the abstract. So long as the domain of the problem area is restricted, the loss of realism may not be important. For example, so long as the surveyed piece of the earth's surface is small enough, it makes more sense for surveyors to disregard the curvature of the earth's surface when they measure elevations. The error induced by this simplification is unacceptable when larger pieces of real estate are traversed, so a more complicated (and realistic) view of the world is necessary.

As long as water conditions are close enough to average, it makes sense for water managers to assume that water allocation and use are established by operating policies. But severe droughts can cause significant changes in water allocations and impacts, often years or decades after operating policies have been set. The premise of this introduction, supported by the testimony of water managers who have gone through severe droughts, is that drought plans that disregard this complexity will not be effective during a drought.

Decisions made about water during drought are affected by how decisions are made under normal circumstances. This includes how concerns about water use, quality and supply are balanced, what water sources are used, and how the infrastructure for treating, storing and distributing water is financed and maintained. Those water related decisions are in turn affected by the way decisions are made about governance, commerce, and personal behavior. Even these overarching decision processes can have an obvious relevance to drought issues, such as consumer response to demand management measures, jurisdiction on water allocation decisions, and the use of water markets.

A useful structure for the rules of decision making has been proposed (Ostrum, 1977) and used in the study of water management, including the National Drought Study (94-NDS-13). In this structure, water management decisions are formed according to three levels of rules: ***operational***, ***collective choice***, and ***constitutional***. Physical characteristics, such as reservoir capacity, are included as part of “scope rules” that define the physical domain of the decision making. Water managers make day to day decisions according to operational rule. Operational rules are changed from time to time to reflect changed circumstances, such as the growth in population, or new use for water. These changes in operational rules are made at the collective choice level. An example of such a rule change would be an interagency agreement on a new drought response plan, or Federal legislative and executive actions to construct a water project. Collective choice rules can be changed only at the *constitutional* level. The U.S. Constitution is a good example of such a rule set. It establishes fundamental concepts regarding the right of governments to manage water, and the division of that responsibility between the federal government and the states.

A team developing a plan to improve the regional response to future droughts works at the collective choice level to define the operational rules for water management during future droughts. The team’s work is authorized and funded under broad constitutional level rules about the responsibility and power to manage water.

The linkage of operating rules to higher level rules illustrates why elected officials are ultimately held responsible by citizens who suffer the impacts of drought. Water managers who have gone through droughts experience this linkage through increased political interest in their decisions. The methods developed during the National Drought Study help elected officials and agency staff share information before drought, when both groups are under less pressure and have more time to develop better ideas.

Many social scientists refer to the sets of rules for making rational decisions as ***institutions*** (not to be confused with another, related meaning of the word, *organizations*). *Institutional analysis* is the study of these rule sets and their consequences on the attainment of human goals.

The phrase "***institutional study***" has a narrower common usage in the water resources field. It typically refers to efforts that analyze whether changes in collective choice rules (such as agency jurisdiction and mission, interagency coordination, and law) will allow improvements in water management that could not be obtained by fine tuning the operational rules. Much of the criticism of current American water management focuses on institutional problems (NDS-1, Rogers 1993).

Changes in the way water is managed, for drought or any other circumstance, can be expressed and analyzed as changes in this structure of rules for making decisions about water.

GOALS AND OBJECTIVES FOR MANAGING WATER

Goal and objective are often used synonymously, but the derivation of each word suggests a useful distinction between the two words. "Goal" is derived from a Middle English word *gol* ("a boundary"). Objective is derived from two Latin words, *ob* ("towards") and *jacere* ("to throw"). In their root sense, then, a goal is an ultimate purpose, whereas an objective is something aimed or striven for more immediately. The ultimate goals for managing water are found in concepts like health and happiness. To direct us towards those goals, we define objectives such as greater environmental quality, economic efficiency, social well being, equity, national security, and better international relations. The concept of ***sustainability*** is often seen as a direction, rather than a destination. Sustainability recognizes the importance of environmental objectives for long term human (economic) use of natural resources. It places greater importance on future economic output than traditional economic theory, which discounts the value of goods received in the future (Lee, 1992).

Multiobjective water management is the process of making decisions about water after consideration of the consequences with respect to these objectives. (Major, 1977). (Annex A briefly discusses the origins of multiobjective water management. Chapter 7 discusses how to account for and make tradeoffs between objectives.) These national objectives become goals for regional water management efforts, such as drought preparedness studies, while still more specific planning objectives are developed to address regional desires. Regional planning objectives are discussed in more detail in Chapter 4.

OTHER COMMON CONCEPTS IN WATER MANAGEMENT

Multipurpose water management is not the same as multiobjective water management. The most common purposes for water management are navigation, recreation, municipal and industrial use, dilution of effluents, instream biological requirements, hydropower, irrigation and livestock watering, flood damage reduction, and coastal and streambank erosion damage reduction. *Multipurpose* refers to structures or practices involving more than one of these purposes. ***Integrated*** water management has been used recently in different ways, sometimes referring to the analysis of water supply and demand options together, sometimes to the coordination of water quantity and quality options.

A ***watershed*** is a geographic area in which water drains to a common outlet. A river basin can contain many watersheds. Watershed management and river basin management are both based on a desire to manage holistically. However, the potential difference in scale may make watershed management more feasible and the relationship between stakeholders and management groups more effective. The term *problemshed* is a play on words that reflects the fact that in some cases, the problem area may not be the same as the river basin area. Reductions in hydropower, for example, may affect power users outside the river basin where the power is produced because power grids allow utilities to share power over a wide geographic area.

Water can be supplied from ***surface*** or ***ground*** sources. In the physical domain, groundwater and surface water are linked. But the institutions for managing surface and groundwater are usually different and separate, and that can make it difficult to manage the two sources ***conjunctively*** (ACIR, 1991).

The DPS method is based on principles drawn from and consistent with this broader context. It is that consistency that makes the method appropriate for water resources planning and management in general. The next chapter provides an overview of this method.

2 THE DPS METHOD

Bad water management often occurs when facts are confused with values, when means are confused with ends, and when technical judgments are made by citizens and politicians while value judgments are made by scientists and professionals.

- William B. Lord (Water Resources Bulletin,1984)

"In the last twenty years, there has been a proliferation of government reports, scholarly literature, and popular works favoring changes in water policy. Common themes abound ... they often observe that broader planning and basin management are preferable to present approaches. Lawyers, economists, political scientists, geographers, citizen groups, and government commissions all have reached remarkably similar conclusions."

- David Getches (Water Resources Update, Winter 1993)

The DPS method is an embodiment of these common themes. Its strength is not that it includes so much that is new, but that it makes practical and whole what is well regarded in theory. Undergirding the well established planning, evaluation, and implementation steps is the innovation of the shared vision model, a method of visualizing future droughts that would have been impossible before recent advances in personal computers. This chapter describes the DPS approach in general terms, followed by more detailed explanations of the various steps in Chapters 3 through 9.

MAJOR FEATURES OF THE DPS METHOD

Drought Preparedness Studies:

- are joint efforts requiring intergovernmental cooperation with those who have a stake in how water is allocated and used.

- constitute a more general version of the planning methods and evaluation principles of federal Principles and Guidelines (P&G) (See Annex A for more information). The DPS method accommodates the extensive responsibilities of non-federal entities in drought situations.

- are result-oriented. Reports and written plans are by-products of behavioral changes that reduce environmental, economic, and social impacts from drought.

- take advantage of experience, research, and expertise from across the country.

- integrate long and short term responses.

- are dynamic, because plans are exercised in regularly conducted virtual droughts.

ORGANIZATION OF A DPS

Although a DPS is a joint cooperative effort between interested parties, it needs a sponsor(s) to provide funding, and a leader to initiate it. The leader must assure that appropriate state officials, regional agencies, and important municipalities are adequately represented on the working group, as well as important industrial, commercial, and public interest groups.

LEVELS OF DETAIL AND COST

A DPS can be carried out at various levels of detail and cost. Funding of $15-$50,000 might suffice for a regional review led by a state water resources agency or environmental agency, a large urban water agency, or a council of governments. At this level, two to four workshops would typically be held, a preliminary *shared vision model* developed (see page 14), with data provided from readily available sources and from interviews with stakeholders, researchers and interest groups in the region.

If the preliminary review suggests that it would be worthwhile, funding of $100,000-$500,000 should be sufficient to evaluate alternative drought response plans in some detail. A study of this magnitude would include a detailed shared vision model that shows how water would be allocated under the status quo and under alternative plans. The model would also show how well each plan met the criteria established by decision makers. The model would be developed using existing data (updated where sensitivity analysis shows that uncertainty in existing data translates to significant differences in management decisions) and interviews with all major players. At least four workshops would be held. The studies would take from 12-36 months, and would be officially supported by agreements signed by the study partners.

TABLE I. THE SEVEN STEPS OF THE DROUGHT PREPAREDNESS METHOD

1. Build a team and identify problems. (Chapter 3)
2. Develop objectives and metrics for evaluation (Chapter 4)
3. Describe the status quo; that is, what will happen in future droughts if the community does nothing more to prepare itself? (Chapter 5)
4. Formulate alternatives to the status quo. (Chapter 6)
5. Evaluate alternatives and develop study team recommendations. (Chapter 7)
6. Institutionalize the plan. (Chapter 8)
7. Exercise and update the plan and use it during droughts. (Chapter 9)

THE SEVEN STEPS OF THE DPS METHOD

The seven steps are shown in Table I. The approach is derived from federal planning principles, but the DPS method adds two steps to the P&G planning and evaluation process, reflecting the importance of the non-federal role and the predominance of non-structural solutions in water management during drought.

The federal process has one principal objective - to reasonably maximize net national economic development benefits consistent with protecting the nation's environment. In Step 2 of the DPS method, the relevant objectives are developed as part of the study. Step 7 recognizes that solutions requiring coordinated actions sometime in the future will not work unless they are exercised and updated occasionally.

The first five steps to drought preparedness are performed iteratively, that is, the sequence of steps is repeated as more information becomes available for evaluation. It is not unusual for new planning objectives to be added, or existing objectives revised, after the DPS team more clearly understands the extent of the problems. As the number of iterations increase, the number of alternatives decreases, the level of plan detail should increase, and the scrutiny of the evaluation process should become more intense.

Iteration should be used to husband study resources. For example, by delaying development of details on the status quo until a little is done on plan formulation and evaluation, a study team can develop a better sense of where details about the status quo are likely to make a difference in study recommendations. Without this iteration, a hydrologist might be tempted to recreate the entire period of historic flows; but if agreement is reached upon use of two past droughts as target droughts, with an assumed frequency, planning can proceed on that basis.

Probably the most common planning mistake is to skip the development of planning objectives and evaluation criteria (Step 2) and start by examining possible alternative solutions (Steps 4 and 5). In theory, it seems obvious that a drought preparedness study can not be managed for success if the stakeholders have not agreed what success is. In practice, though, working groups usually assume that everyone understands what the objectives are, and that it would be a waste of valuable time to articulate and debate them. These "practical" decisions fly in the face of decades of planning experience. Without clearly stated planning objectives and evaluation criteria, effective decisions on the allocation of study funds and time can only be accidental, and conflicts over differing aims cannot be resolved efficiently.

COMPUTER MODEL BUILDING AND STAKEHOLDER INVOLVEMENT

Projections of how scarce water will be allocated to a variety of stakeholders clearly require mathematical computations. Ideally, these calculations would accurately reflect all the things that would happen during a drought, and at the same time be easily understood by water use groups.

This goal had become more and more elusive because of three trends in water management:

- New water uses and environmental concerns have made multiobjective, multipurpose analyses more complex.
- There are more data and the complexity of data analysis is increasing.
- There is a general trend to broader public participation in water management.

The compounding of these trends has greatly increased the difficulty in making timely and informed changes in water management policies. It has become more and more difficult for water managers, and nearly impossible for stakeholders to synthesize the information generated for an entire water system and use it to make decisions.

There is a gap between the way people make decisions and the information specialized water models can produce. The DPS's used new computer software to create "shared vision models" that bridge that gap.

The National Drought Study used a new method of building computer models of water systems to accomplish this goal. The "black box" computer models typically used in the past were supplemented with new, site-specific planning models created by individuals representing the Corps, local water supply agencies, water managers, and stakeholders who would be impacted by the plans. These models captured the expertise and experience of people in the region and became a *shared vision* upon which to base negotiation.

This integration of planning and modeling differs significantly from previous approaches and has only recently been made possible by extraordinary advances in computer hardware and software. In the past, computer models used in water resources planning were created by individuals specially trained in computer programming. Today, because of the availability and power of personal computers and new simulation software, more people can become involved in building models and the models can be more easily understood by all stakeholders.

The computer software used in these efforts can be described as a user-friendly, graphical simulation tool. This software makes use of icons to represent simple, physical objects or concepts. The model builder selects from a palette of icons to describe the system, such as reservoirs, streams, and uses. After the basic system configuration is defined, the modeler defines system operating policies and provides site specific information such as streamflows, demands, and economic and environmental relationships.

The specific software used to implement water resource system models developed in the National Drought Study is STELLA II®. STELLA II® is most simply described as a visual spreadsheet for systems analysis where the process being modeled can be pictured as a process rather than equations. STELLA II® was selected over other available software because of its unique combination of simplicity, power, and cost-effectiveness.

Because the new software is so user-friendly, members of the working group and stakeholders can participate in the development and testing of the model, and in its application to estimating the effect of various alternative plans considered. This process builds confidence in the model results (see Annex C for more information).

In the National Drought Study experience, this collaboration gave team members a chance to appreciate and understand each others perspectives. Concepts that had been vaguely understood such as *safe yield* and *primary water right* were explained and illustrated in models, so that non-experts could understand the implications these concepts carried for their concerns.

GROUP PROCESSES

The conduct of a DPS requires the successful interaction of people with different values and backgrounds. In recent years, processes have been developed that (when used properly) can make this interaction much more efficient.

There will be several workshops held in the course of even a simple DPS. There are many good books offering suggestions on how to run effective workshops. Here is a summary of some of that advice that is directly applicable to water management workshops.

Agendas should be established in advance of meetings and workshops. If a group meets regularly, development of the agenda for the following meeting can be the last task of the current meeting. Each agenda item should have a set time and discussion leader.

Facilitators are useful in most meetings and should be used in all workshops. Because facilitation requires training, and good communication and interpersonal skills, and because the facilitator should not participate in the substance of the discussion, it is usually better to hire a professional facilitator than to ask for volunteers from within the group. The facilitator's job is to make the meeting effective.

Facilitators make sure that the purpose of each agenda item is fulfilled; help the group to manage their meeting time; manage dominant and passive participants; clarify miscommunication among meeting participants; and assure that necessary follow-up actions are assigned to a responsible party.

Brainstorming is a process which has been used extensively in value engineering and other areas where innovative alternatives must be found. It is best done in small groups led by a recorder who simply lists every idea that is offered by any member of the group.

The key to successful brainstorming is to withhold criticism until the group has exhausted its creativity. This can be very difficult, especially when water experts brainstorm with stakeholders, because many of the ideas will have technical flaws or will be unresponsive to the planning objectives.

Encouraging all participants to freely offer solutions achieves many ends: it can allay fears that possible solutions have been overlooked; provide the insight of a fresh perspective to an expert; force the examination of good ideas that experts know have powerful foes; or allow interesting, but ultimately unsuitable ideas to be raised and rejected in an equitable and public manner.

After the uncritical brainstorming, participants should eliminate redundant ideas, and then use preliminary screening criteria to reduce the number of alternatives. Brainstorming can be used to assemble a collective response better than the best ideas of any participant. But if none of the participants know much about a subject, the collective answer will also be uninformed. Unfortunately, it has become much more common to see brainstorming used in this way. Brainstorming with agency staff alone is not sufficient to identify stakeholders' needs. Especially during the first step of the DPS process, brainstorming with stakeholders is a valuable supplement to a review of previous reports on water resources problems in the basin.

Brainstorming with stakeholders alone will not produce solutions that are technically adequate. During the fourth step of the DPS process, stakeholders should be encouraged to express their ideas for alternatives, but the preliminary screening process should allow experts to use their knowledge to explain why some ideas should not be studied further.

A ***Delphi*** process can accomplish some of the same purposes over a longer period of time, but without a physical meeting. In a Delphi process, experts are asked to respond to a series of questionnaires about problems or solutions. A central analyst reviews their answers, then develops another questionnaire if needed to clarify or resolve disputes among the experts, or to address new issues suggested by the previous round of responses (Delli Priscoli, 1986).

Chapter 7 explains how teams can screen a long initial list of alternatives to produce a manageable number for more detailed analysis.

The remaining alternatives can then be organized if that serves a purpose. The use of 8½"× 11" paper rather than flip charts allows participants to group ideas before having to agree on category names.

Breakout sessions. Research and experience show that it is very difficult for groups of more than a dozen or so people to work effectively on an intellectual product. An hour provides only 5 minutes of verbalization each to 12 people! Larger groups are acceptable if individual contributions are less important, in such activities as listening to a speaker or voting.

BUILD A TEAM, IDENTIFY PROBLEMS

Decision making should include all affected interest groups.

- Long's Peak Working Group (America's Waters: A New Era of Sustainability, 1992)

Efforts to deal with water geographically typically encounter strong resistance from bureaucracies that are functionally organized for different purposes.

- Peter Rogers (America's Water; 1993)

There is a natural, physical integration of water problems in a river basin; the challenge is to assemble a problem solving team that can work with a corresponding wholeness. The first step in the DPS method was designed to overcome two common shortcomings in water management: the separation between stakeholders and the problem solving process, and the subdivision of natural resources management by limited agency missions. Each problem will affect a group of stakeholders and be managed by one or more agencies. This chapter explains how to assemble such a team.

The first step in the DPS method is to assemble a planning team and determine the nature of drought problems the region faces. The discussions of study process in this and other chapters assumes that there is a lead agency (see Chapter 2) that invites participation on a DPS team and facilitates an initial problem identification workshop.

DPS's are meant to produce behavioral changes that will reduce regional vulnerability to drought. One of the most imposing roadblocks to such action is the fragmentation of responsibility caused by the mismatch between political and hydrologic boundaries and between agency missions and water resources problems.

Rarely will there be one agency or political entity that can tackle these problems alone (See Chapter 1). The DPS team will be a new entity whose makeup reflects the set of problems: the stakeholders that will be hurt by drought; the agencies that have will make decisions related to the drought; the advocates whose concerns are elevated by drought; and the independent experts whose life studies are applicable to drought.

In a DPS, water managers and stakeholders work together to specify problems and develop solutions. Compared to the more common approach in which water managers develop plans and then present them to stakeholders in public meetings, this collaborative approach:

- harnesses the knowledge and creativity of stakeholders near the beginning of problem solving efforts;

- makes it more likely that stakeholders can take actions unilaterally to reduce their drought vulnerability;

- builds broader, deeper stakeholder support for water management plans.

Water managers do not surrender their responsibility or authority because of this collaboration. In fact, the water management decisions are less likely to be challenged if managers develop public understanding, input, and support prior to the drought.

MAKEUP OF THE TEAM

The planning team should include four types of people: stakeholders, water managers, advocacy groups, and independent experts. Depending on the problems involved, team members of each of the four types should be selected to represent national, regional, or local interests, and may be drawn from the private as well the public sector. Water managers make or implement decisions. They include agency staff involved in planning, operation, and regulation, and elected officials ultimately responsible to citizens for drought responses.

A conscious effort should be made to involve those with long term management responsibility and oversight, even if their particular interest is not drought. Because of the integrated nature of a DPS, its recommendations may need to be woven into processes and cultures beyond drought management. Examples include legislative aides with water policy oversight, water supply and wastewater planners, and regulatory staff.

Advocacy groups support positions on particular issues such as protection of the environment or growth management. The DPS method encourages participation of diverse interests from the beginning, in order to reduce the chance of litigation that has characterized past studies. Such a collaboration requires advocates to assume some responsibility for achieving regional goals, and requires agencies to share information and power. Annex B summarizes the results of a study by the U.S. Advisory Commission on Intergovernmental Relations (ACIR) on methods of effecting better cooperation among agencies, elected officials, and advocacy groups.

STARTING THE DPS

The DPS will typically begin when a convening agency writes to the heads of other agencies and organizations representing the four types of participants and invites them to send representatives to a workshop. At the workshop, the convening agency should facilitate the initial effort at defining the range and severity of drought problems facing the region. Participants at this workshop should also consider who is *not* at the workshop but should be involved in the study.

It is essential that decision makers make a commitment to empower the DPS process. In extreme cases, when a collaborative study is an alternative to litigation, the decision makers' commitment to act according to the findings of the study should be formally established at the beginning of the study. Less formal commitments are acceptable, but the same concept applies: stakeholders have no reason to participate in a process that will change nothing. The DPS should be launched with letters of support from the decision makers.

During the study, the support of decision makers must be manifest at least through the commitment of agency staff time. The goal of this collaboration should be an agreement by agencies and stakeholders to manage water according to the findings of the study.

FINDING STAKEHOLDERS

Unless they have recently been personally involved in a drought, stakeholders are often unaware of their vulnerability and will not make individual preparations to reduce their vulnerability. Stakeholders competing for water often make their first contact with water managers and competing stakeholders during drought, when they are most threatened by drought impacts.

Table V lists the primary water management purposes likely to be affected by drought. It can be used as a checklist for identifying drought problems and building a study team.

POTENTIAL PROBLEMS OF BROAD INVOLVEMENT

Broadening study participation may also pose some problems:

- money spent on public involvement will not be available for technical studies.

- the "public" that gets involved in planning may be self-selected and unrepresentative of the public that will be affected by drought.

- if public representatives are actually involved in the study process (as opposed to just expressing problems and goals in workshops or surveys), then additional efforts may be required to provide technical training and to coordinate the work of public task forces.

- the misapplication of the techniques of group process (see page 16) can result in the use of stakeholder opinions on issues that should be addressed by experts.

- all group processes can be slowed or stopped by recalcitrant or distrustful participants, and broader citizen participation increases that risk by adding more participants.

The methods described below are designed to allow broad representation *and* effectiveness.

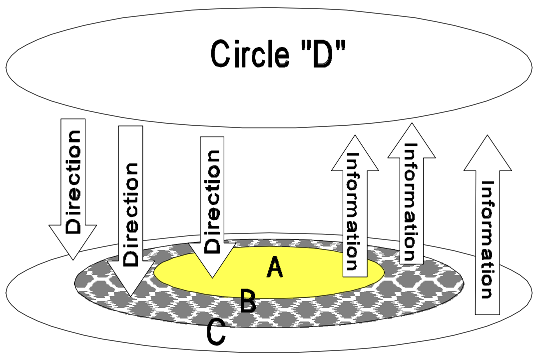
CIRCLES OF INFLUENCE

The DPS teams used a simple approach called "circles of influence" to help strike a balance between the effectiveness of small teams and the representativeness of large teams. This approach is built on the common themes in three very different examples of organizational effectiveness (none water related) and is consistent with research on how people work together well. (For more information, see Annex J).

Although there is no formal "membership", individuals involved in a DPS can be described as belonging to one of three circles, A through C. Each successive circle from A through C has broader representation but less personal involvement. If one were to develop a composite of the four DPS's of the National Drought Study, Circle A managed the study and did most of the actual work. Circle A included the Corps study leader, as well as 2 to 4 others from outside the Corps. They spoke several times a week, managed contracts, arranged meetings of larger groups, built models, did research, and wrote letters, papers, and reports.

Circle B includes Circle A as well as one representative for each major stakeholder group (such as industrial users). Circle B will probably need to meet a few times a year. They may review and revise draft papers from Circle A.

FIGURE 2. CIRCLES OF INFLUENCE



The ideal circle B participant will be active in professional or issues oriented organizations. They would also be trusted and respected by others whose interests he or she represents. The activity of the participant outside the DPS is important because it takes advantage of existing channels of communication. And if the Circle B participant was trusted and respected, stakeholders outside Circle B were more willing to support the study despite their decision to be less directly involved in the study.

Circle C included a representative from each major stakeholder, each management agency, and each advocacy group. Circle C numbered from 20 to 60, and met twice a year in fairly formal workshop settings.

Regional decision makers (agency heads and elected officials) constituted a fourth circle, "D". They were involved formally at the beginning and end of the DPS's, and were kept informed during the study through their study representatives.

Every stakeholder and decision maker outside Circle A was connected to "A" in an identifiable chain. These connections were usually through common work places, related work groups, or professional organizations. The connections were based on a combination of trust and communication. Individuals who wanted more influence or oversight were free to move into the central circles if they were able to contribute more time to study tasks.

When existing organizations are too restrictive to deal with water issues in a holistic way, circles of influence can create new ways for people to interact, without destroying the old organizations or their responsibilities and advantages.

Circles of influence supplement, but do not replace procedures that require consultation with other agencies or public hearings.

THE PROBLEMS

Existing reports written by researchers and management, data and regulatory agencies should be used as the basis for problem identification. Participants at the first workshop should describe past impacts and the efforts to mitigate those impacts, addressing the following questions:

- What problems have they experienced in the past?

- What efforts to prepare for future droughts are they aware of?

- What changes in hydrology or water use since the last drought have affected the region's vulnerability to drought?

- Are they still vulnerable individually?

- Is the region still vulnerable?

- Can the DPS help or be helped by other ongoing work?

- How can regional vulnerability be reduced without their personal commitment?

- What benefits could the region realize if its vulnerability to drought were reduced?

- What is the appropriate geographic scope? The starting point should be the river basin or watershed. If problems exist and can be managed in a portion of the basin, then the study should focus its attention there. If there are out of basin diversions, or if hydropower produced within the basin is used elsewhere, then the team may decide to broaden the study area. None of this may be apparent at the first workshop, but as the study progresses, the team should revisit this question to assure that study efforts are explicitly shaped to the problems.

A simple table such as Table II can be constructed at this first workshop to describe the participants' best sense of how vulnerable they are to mild, severe, and very severe drought.

The second column in Table II describes how the various groups believe they would be affected by a non-drought water shortage. Participants should also consider taking advantage of the opportunities provided by the DPS to manage water shortages caused by polluting spills, earthquakes, flooded water treatment plants, and aqueduct breaks. Responses to these emergencies often require collaboration among the same agencies involved in drought management. If emergency procedures are already in place, then some of the coordination mechanisms can be used for the drought study. If emergency plans are inadequate, participants may decide to improve them during the DPS.

Each participant should be asked whether the group they represent is prepared for future droughts, and if they feel that the region as a whole is prepared. If the general consensus is that there are serious problems, then the group must ask if there is an organized effort outside the DPS to address these problems. There may be an opportunity for mutual benefit if long range water supply studies, federal feasibility or reservoir reallocation studies, legislative reviews of existing water laws and regulations, or urban planning studies are underway. Even if efforts outside the DPS do not address drought issues directly, there may be an opportunity to share data, computer models, and even political support.

Finally, the participants should ask themselves whether these problems will be addressed without their personal commitment for making the DPS successful.

Moreover, because history has shown that concerns about drought dissipate soon after droughts are over, participants must also realize that unless they become advocates for change, the change will not occur.

Once the basic team structure has been set up and the major problems identified, the next

TABLE II. THE FIRST WORKSHOP: EXPERTS' UNQUANTIFIED SPECULATION ABOUT EXPECTED IMPACTS FROM FUTURE DROUGHTS

Incident → Group ↓	Emergency: Oil Spill	Moderate Drought	Drought of Record	Worse Than Record Drought
Navigation Industry	Short term impact.	No problem	Slight to moderate reduction in service	Moderate to severe reduction in service
Wastewater Treatment Agency	Shutdown	Failure to meet effluent standards	Failure to meet effluent standards	Failure to meet effluent standards
Environmental Groups	Wildfowl, fish kills	Concern about low levels of dissolved oxygen	Demands for reservoir releases	Demands for reservoir releases
Flat Water Recreation Industry	Little effect	No problem	Financial difficulties, resistance to releases	Bankruptcies
White Water Recreation Industry	Long and short term declines in business	Decline in business	Some bankruptcies	Many bankruptcies, long term loss of customers
Domestic Water Users	Short term crisis	Voluntary curtailment	Mandatory curtailment	Severe, mandatory curtailment
City Water Supply Agency	Criticized because of no plan	Little impact	Some public criticism	Severe public criticism
Electric Power Industry	Little effect	Cost of electricity may increase.	Cost of electricity will increase.	Cost of electricity will increase, brownouts will be necessary

TABLE III. THE TYPES OF PEOPLE THAT MIGHT WORK IN EACH OF THE CIRCLES OF INFLUENCE

Circle → Categories ↓	A	B - includes A, adds:	C - includes B, adds:	D: Decision Makers
Agencies	Corps, City and State Water Department Staff	State Fisheries staff	Other Corps, State offices, city water departments.	Mayor, Governor, Chief of Engineers or authorized designate
Users	Hydropower industry staffer	One professional from each purpose (e.g., the Hydropower Industry)	Technical representatives from all corporate users	CEO's, Electorate
Advocates	Professional citizen representative	Environmental Group representative	One representative from all relevant environmental groups	
Experts	University: Hydrologist/ Environmental Engineer/ Resource Economist		Political scientists, engineers	

Legislators may occasionally be Circle D decision makers if new laws are required to effect reduced drought impacts. More universally, though, they are an important medium through which the goals for managing water are articulated; they are directly responsible to the public. While they may not be included in a circle, their views on the appropriate goals for a drought response plan can be solicited in an issues study (see page B-3.)

step is to define what the team is trying to do in measurable terms. As the preparedness effort progresses, though, the problems may be restated (new problems discovered, other problems de-emphasized).

The composition of the team may change as well, with some individuals comfortable with a smaller role, while others decide to do more work and secure more influence in an inner circle.

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4 OBJECTIVES AND METRICS

The success of drought response plans should be measured in terms of the minimization and equitable redistribution of the impacts of shortages, as opposed to the shortages themselves, but there is much to be learned about the best ways of accomplishing that.

Lessons Learned from the California Drought (1987-1992) (NDS-5)

A successful DPS team will reduce drought impacts through the implementation of their recommended measures. But what makes one plan better than another? And what criteria will those who must approve the plan demand that it meet? Until the DPS team identifies the criteria that define a successful study, they cannot manage to succeed. This chapter explains how DPS teams can use five kinds of objectives and measures.

MANAGEMENT

The DPS team should identify and articulate management guidelines in five categories:

- *decision criteria* that define broad goals and must be satisfied for the DPS recommendations to be implemented;

- *planning objectives* that spell out how and when the DPS team hopes to affect specific water uses;

- *constraints* that specify what are undesirable, prohibited, or physically impossible outputs from the DPS;

- *performance measures* of the water system, and

- *effects* of alternatives on the environment, the economy, and social well being.

DECISION CRITERIA

No matter how well the DPS recommendations work on paper, they will not reduce impacts unless they are approved and implemented. As part of the conscious effort to improve their chance of implementation, DPS teams should identify who will need to approve their recommendations and what criteria they will use in making that decision.

Planners studying the feasibility of federal water projects are told what the criterion is: they are directed to recommend the plan that reasonably maximizes net National Economic Development (NED) benefits while meeting environmental constraints. The evaluation of alternatives in federal studies is designed to address that criterion.

But non-federal decision makers will use other criteria. In some cases, the criteria will be very difficult to determine. For example, in deciding how early to declare a drought, different decision makers may favor different tradeoffs between the risk of catastrophe and the frequency of inconvenience.

Some criteria will not be acknowledged or shared with the DPS team; they may constitute a hidden agenda or may be difficult to articulate.

The difficulty of defining all of these criteria does not diminish the need to address those that decision makers are willing to share with the DPS team. Determining the criteria that elected officials will use may be especially difficult for agency staff. In two of the National Drought Study DPS's (the James River and the Cedar and Green River), political scientists were hired to identify and interview the political and agency leaders that would ultimately have to approve (or veto) plans developed by the DPS's. The interviewers were well informed on the DPS planning, modelling, and evaluation process, enabling them to share information about the DPS with the elected officials. The interviews and subsequent summary reports helped to close the perspective gap between agency staff and elected officials.

GOALS AND PLANNING OBJECTIVES

The goals of a DPS will probably change only in degree from place to place; inevitably, people will be concerned about economic efficiency, environmental quality, and fairness. (See page 9 for a discussion of the difference between goals and objectives).

To spell out specifically what the community hopes to achieve by preparing for drought, the DPS team must identify drought related problems to be solved and opportunities that could be realized. The team will develop regional **planning objectives** related to those problems and opportunities. Examples of problems and planning objectives are shown in Table V.

A planning objective is a concise, formally structured statement which explains how and when a study will try to affect a specific water use in a specific place.

Developing good planning objectives early is paradoxically the most important and most often ignored step in the planning process. How can a team <u>manage</u> to achieve objectives if they have not agreed on what those objectives are?

Planning objectives will often conflict with one another because they reflect the competition for water. Although objectives should be quantifiable, so improvement can be measured, a specific numerical goal should not be specified as part of the objective. Doing so implies that conflicting objectives must be sacrificed until that level is met. The degree to which each objective is met must be determined by the evaluation process in which each plan's economic, social, and environmental outputs are compared.

TABLE IV. WRITING A PLANNING OBJECTIVE.

Describe the **problems** in a sentence or two.	***During a recent drought, the number of whitewater rafting days was severely restricted, with millions of dollars in lost regional revenue.***
Use a **verb** or **action phrase** which expresses what the team is trying to do (increase, enhance, reduce, mitigate, etc.) regarding a **resource** (water withdrawal, instream flows, etc.) in the **context** of the perceived value of the resource (M&I uses, fish habitat, etc.).	***increase the number of days of whitewater rafting***
Add to that clause (verb, resource and context), the **geographic area of concern** (in the lower James Basin).	***between Ogle Point and Deadman's Whirlpool***
Finally, say whether this is a dynamic or static change. If demand is not expected to change in the future, then the problem strikes whenever a meteorological drought occurs. But if demand is increasing, or becoming more complex, then the problem may occur more often or to a greater degree in the future. The former condition can often be remedied completely with a tactical drought contingency plan. The latter may be better addressed in strategic planning because demand is outgrowing the structures, institutions and laws which were once adequate.	***during droughts*** would be static; if conditions were expected to change for better or worse, then that should be stated as part of the objective: ***during droughts until the Oglethorpe water supply project is completed***

Verbs commonly used in the action phrase include: advance, compensate for, conserve, contribute to, control, create, destroy, develop, eliminate, enforce, enhance, establish, exchange, improve, maintain, manage, minimize, mitigate, preserve, produce, promote, protect, provide, reclaim, reconstruct, recover, recreate, rectify, reduce, rehabilitate, repair, replace, restore, retire, stabilize, or substitute.

TABLE V. PLANNING OBJECTIVES FOR A TYPICAL DPS

Kanawha River Basin DPS Planning Objectives

Problems: During a drought ...	Planning Objectives
1. Whitewater rafting on the Gauley River is restricted.	1. Increase the reliability and value of the Gauley River whitewater rafting experience during drought conditions.
2. Corps reservoirs are drawndown to meet downstream water needs. In-lake recreation suffers when drawdown is significant.	2. Increase reliability of the recreational opportunities on lakes in the Kanawha River basin during drought.
3. Normal navigation pools could be difficult to maintain resulting in disruptions to navigation traffic.	3. Maintain navigation on the Kanawha River during drought.
4. Flows in the Kanawha River could decrease such that losses to hydropower generation at the 3 Corps of Engineers lock and dam projects could occur.	4. Maximize hydropower generation in the Kanawha River basin during drought.

Examples of things which are not planning objectives:

- To *increase economic benefits* (this is a broad goal at the regional level, and cuts across several objectives - see Chapter 1 for a discussion of goals and objectives).
- *Build a desalting plant* (This is a *means*, not an objective).
- *Eliminate water supply shortfalls* (Measures should be “sized” after consideration of their costs).
- *Assess the impacts of droughts* (This is a study procedure, not an end in itself.)
- *Reduce groundings in the channel* is too narrow; this could be achieved by banning navigation. The objective could be to *improve navigation between (point A and B) during drought*.
- *Maintain instream flows between river miles 300 and 305 at 800 cfs or above* is a constraint, rather than an objective. But a complementary objective may be more useful; a team may find a way to *enhance water quality fish habitat between river miles 300 and 305 during droughts* other than enforcing a minimum flow at all times.

CONSTRAINTS

Constraints express what may not be done under existing institutions. Typical constraints include requirements to maintain a specific rate of instream flow, or to satisfy laws regarding priorities in the right to use water. Although not generally characterized as planning constraints, the physical limitations of storage and transmission facilities are conceptually no different from legal constraints. Constraints that prohibit certain alternatives are antithetical to the concept of multiobjective evaluation, and DPS teams should consider challenging them if they stand in the way of meeting objectives. There will be an additional burden of proof, however, imposed on a DPS team that recommends a plan that violates constraints that constitute clearly stated, publicly resolved decisions.

Planning objectives and constraints are used:

- as screening criteria in the initial evaluation of alternatives. Plans that address only some of the objectives or fail to meet constraints may be eliminated or force a reformulation of the objectives.

- as management criteria used in deciding how to allocate study resources among geographical and topical areas.

- as a basis for identifying quantifiable measures of system performance. For example, the number of days when flows are above 1200 cfs and number of days with flows above 800 cfs might be useful measures of the degree to which the objective “increase the number of whitewater rafting days during drought” is met.

PERFORMANCE MEASURES

The study team should also develop statistical measures of the performance of the water system relative to the needs of the user. The development of these measures is essentially a technical assignment, but the acceptance and relevance of performance measures can be confirmed in workshops and stakeholder interviews. Examples of performance measures are shown on Table VI.

EFFECTS OF THE ALTERNATIVES

Performance measures do not provide a basis for tradeoffs among conflicting objectives. For example, reducing the frequency of navigation restrictions through increased releases from a reservoir may increase the amount of time boat ramps around the perimeter of the reservoir are out of the water. To what degree should each be sacrificed?

In a multiobjective analysis, the *effects* of the loss of each activity on the basic objectives (regional goals) for managing water are estimated. The most commonly considered objectives are economic efficiency, environmental quality, social well being and equity. The usefulness of this approach is most obvious when the effects of the alternatives accrue against only one objective. If, in the example above, the only differences between preserving navigation and recreation were economic, then it would make sense to balance the level of navigation and recreation to maximize economic benefits. Chapter 7 discusses ways of informing the negotiation of multiobjective tradeoffs.

TABLE VI. TYPICAL MEASURES OF PERFORMANCE

Water Use Category	Typical Performance Measure
Municipal	Frequency of failure to meet unconstrained demand.
Industrial	Frequency and duration of supply failures.
Navigation	Frequency and duration of channel closing or imposition of light loading requirement.
Lake Recreation	Frequency and duration that boat ramps are out of the water.
River Recreation	Frequency and duration of depths or flows too low for recreation.
Hydropower	Power produced, or frequency of failure to meet minimum levels of production.
Fish Habitat	Frequency of failure to meet minimum flow targets.
Irrigation	Probability of failure to supply water need for this year's plantings.

ACCOUNTS

An alternative may produce economic effects by changing the level of activity in several water purposes. For example, changing the rules for reservoir releases may change the level of hydropower production, navigation and several forms of lake and riverine recreation. The change in each activity will have economic consequences.

Establishing an *account* for these economic effects allows the total economic effect of an alternative to be summed and compared to the total economic effect of other alternatives. Accounts can also be established for environmental quality, social well being, and equity, although (unlike the economic account) there is almost certain to be more than one unit of measurement for the effects within any one of these accounts.

The use of the accounts not only helps organize the effects, it can help planners understand distinctions between the *ends* of different stakeholders who support the same *means*. For example, a team may be working under a constraint to provide instream flows for fish. The constraint may be managed by an state fish and game agency and supported by a Native American tribe, an environmental group, and an association of small businesses that outfit tourists who come to fish. The number of days that streamflows fell below the minimum standard would be a simple, useful performance measure, but it would not reflect the complexity of the effects of failing to meet the standard.

The environmental group might support the minimum flow standard because it helps preserve a threatened or endangered species (an environmental effect). The tourists may be concerned about the decreased opportunity to fish, an impact that can be measured in *economic* terms according to their willingness to pay for that experience. The outfitters would have a special concern for their own viability. If reducing instream flows would bankrupt a class of businesses, that alternative might be judged inequitable. The tribal concern could be for the maintenance of a traditional, formal *social* activity. Knowing the ultimate objectives of each stakeholder group can help DPS teams develop and estimate the acceptability of alternative management plans.

RESISTANCE TO THE USE OF ESTIMATED EFFECTS IN THE EVALUATION OF ALTERNATIVES

It may be difficult and expensive to estimate the effects of alternatives. DPS teams must carefully consider the following questions before deciding what effects should be measured:

- do the decision criteria demand an estimation of effects? In federal feasibility studies, the selected plan must reasonably maximize net NED benefits. If one of the alternatives in a DPS involves the modification of a federal water project, then NED evaluation is essential. Changes in the operating policies of a federal reservoir require an environmental assessment.

- will tradeoffs between regional planning objectives be necessary? In the Kanawha River DPS, an alternative was identified that helped many stakeholders and hurt no one. But if no such alternative can be found, then alternatives can only be compared to one another using estimated effects.

- are financial costs involved? If so, then the estimation of effects can be used to determine an appropriate level of investment.

ADVANTAGES OF THE MEASURING EFFECTS BY ACCOUNT

The impossibility of defining and measuring these effects perfectly may frustrate some DPS teams and preclude them from these benefits of imperfect estimations:

- estimates of economic effects can suggest the underlying value of water use and encourage the use of water markets, dry year options, or other similar alternatives in which the use of water is traded for money. Similarly, differences in economic benefits among plans can be used to justify different levels of investment.

TABLE VII. A CHECKLIST OF WATER USES, PROBLEMS, PLANNING OBJECTIVES AND PERFORMANCE MEASURES

CHECKLIST OF WATER USES, PROBLEMS, AND EVALUATION MEASURES

	Water Use	Problem	Planning Objectives	Measures of Performance	Decision Criteria	Related Economic, Social, Environmental Impacts
Offstream	Irrigation					
	Livestock Watering					
	Municipal Water					
	Industrial Water					
Instream	Hydropower					
	Lake Recreation					
	River Recreation					
	Water Quality (Dilution)					
	Fish & Wildlife Habitat					
	Flood Control					
	Navigation					

5 THE STATUS QUO

A drought preparedness study goes beyond a simple determination of future resource conflicts; it serves as a motivator for conflict resolution. Without knowing your status quo future, you lack a basis for motivation. After all, if you don't know where you're going, why plan any changes?

Richard Punnett (Huntington district, Corps of Engineers)

The ***status quo*** *is simply a collective best estimate of what future droughts will be like if the DPS fails to make a difference. It serves as the baseline from which to measure the strengths and weaknesses of alternative drought responses, and a consensus view of the problems stakeholders will face if they fail to agree on an alternative. Dr. Punnett's reflection is drawn from his own experience leading a DPS workshop of stakeholders who had competed for water in a 1988 drought. He had presented a clear vision of what would happen in future droughts under existing operating rules. The stakeholders, who had participated in the construction of the computer model of that vision, supported a combination of two alternative plans that hurt no one, and helped many. Whitewater rafting outfitters rejected a plan that would have provided them with even more water because the shared vision model showed that it would decrease lake recreation. The outfitters acknowledged that it made little sense to hold out for the alternative that maximized their gain while hurting other stakeholders, they almost certainly would have been left with the status quo. This chapter explains how the status quo should be defined and modeled.*

Whether the subject is property lines, mountain elevations, or drought impacts, measurements cannot be compared unless they are referenced to a *baseline*. The third step of the DPS planning method is to create a baseline by describing the future without the DPS; that is, how the region would respond to and how it would be affected by droughts if no actions are taken as a result of the DPS. This future without the DPS is referred to as the *status quo*.

The status quo should reflect developments that will change drought impacts **so long as their implementation is not related to the DPS**. These developments include such things as additional water supplies, drought contingency plans, and external conditions such as projected increases in population and economic activity.

The status quo can also provide motivation to a DPS team to produce results, because the status quo is a thoughtful, detailed, and collective forecast of what the future will bring if they do not.

In some cases, stakeholders may refuse to agree on aspects of the status quo they are contesting outside the DPS. For example, two stakeholders may have opposing positions on a permit application for a new water supply source, and may feel that to publicly accept an outcome opposite their position as "most likely" will be considered a reflection on the merits of their case. In such cases, DPS teams can fulfill the baseline requirement by selecting one of the possible futures without claiming it is the most likely scenario.

The effects of drought contingency plans, water laws and institutions as they currently exist should be reflected in the status quo. This should include the basic water allocation system, of either riparian or appropriation type, any site-specific programs, provisions for public trust and instream flows, water conservation, transbasin diversions, and ground water management (all are discussed in Annex D). Some of these provisions are of particular importance, as indicated in the following paragraphs.

The DPS team should carefully define the thresholds for implementation of extreme measures. For example, every western governor has the authority to "condemn" water rights during a drought, which is to take the right to use water from private owners if it is needed for the public good. However, this is an extreme measure, however, and has never been used (Willardson, 1986).

The DPS team must now try to quantify the problems that were identified in general terms in step 1 (Table II). To do that, they will:

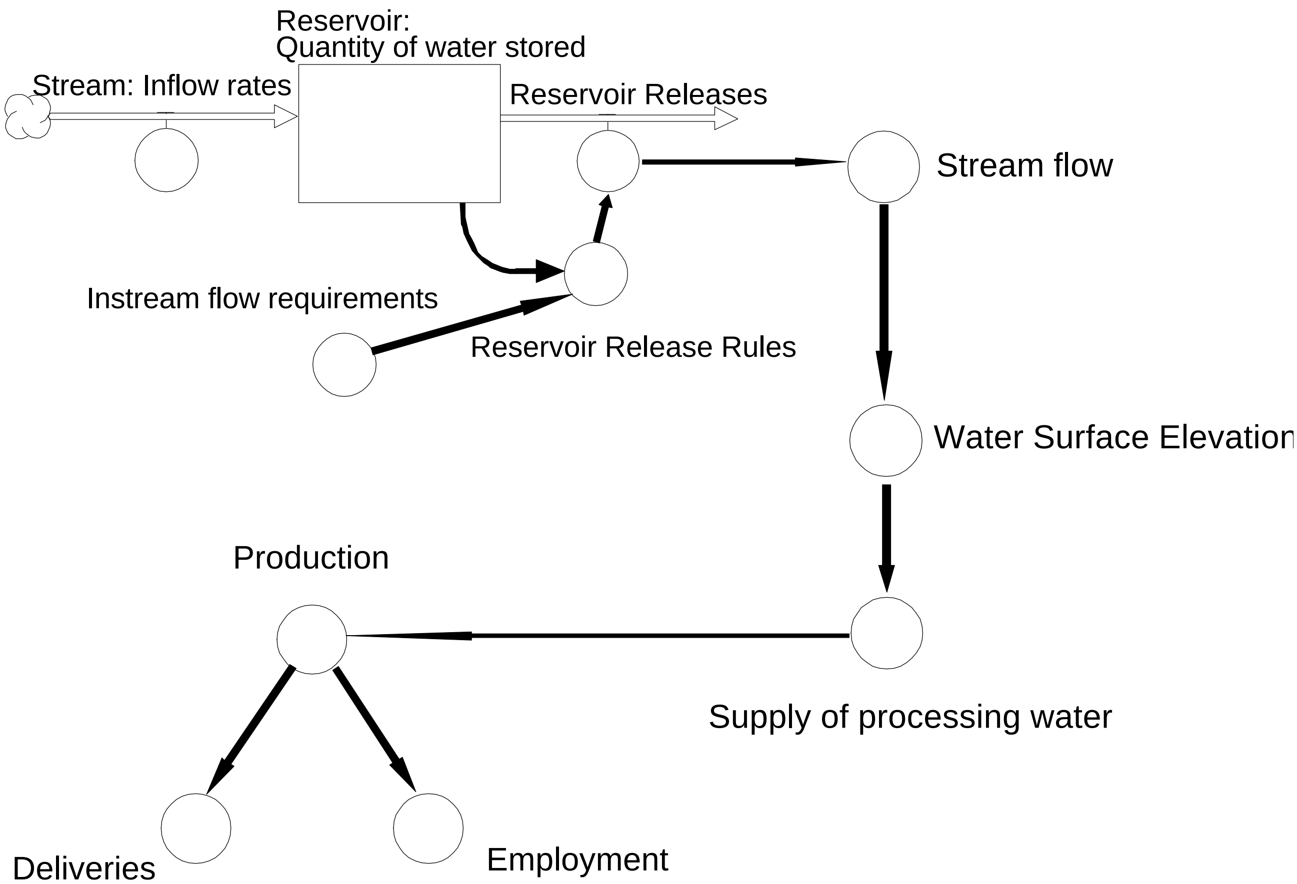
- Build a model of the water management and allocation system with involvement from stakeholders. The model should include the relationship between shortfalls in water deliveries or levels and the impact on stakeholders.
- Make hydrologic estimates of drought frequency, and select the design droughts.
- Measure the performance of the water system during the design droughts.

The next several pages illustrate how that might be done.

● The shared vision model of the status quo should define the relationship between water and the stakeholders ultimate purposes for using water. These relationships can be developed though interviews with principal stakeholders. The specific situation of each stakeholder may even be modeled during the interview. In the example illustrated below, one stakeholder is an industry that uses water drawn from a stream as part of its production process. In a severe drought, stream water surfaces may drop so low that the intake is no longer submerged.

Figure 3 illustrates how the relationship between stakeholders' ultimate needs and the water management system can be diagrammed.

FIGURE 3. A SHARED VISION MODEL CAN ILLUSTRATE HOW STAKEHOLDER CONCERNS ARE CONNECTED TO MANAGEMENT OF THE WATER SYSTEM



MODELLING THE STATUS QUO (CONTINUED)

In this example, employment and deliveries - the factors most directly related to stakeholder profitability and viability - are dependent on production, which in turn requires processing water. The same icons used to diagram these relationships (Figure 4) are used to quantify them (Figure 5). The modeler defines the function relating production to the supply of processing water by "double-clicking" the computer mouse when the computer cursor points to the icon representing "production". These functions can be defined based on existing and new studies, including interviews with the stakeholders during the DPS.

FIGURE 4. THE RELATIONSHIP BETWEEN WATER AND PRODUCTION FOR ONE STAKEHOLDER.

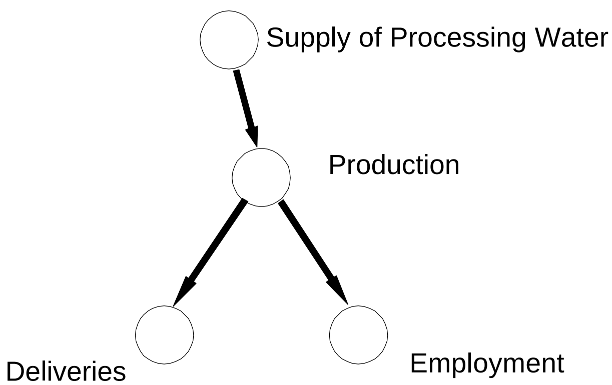
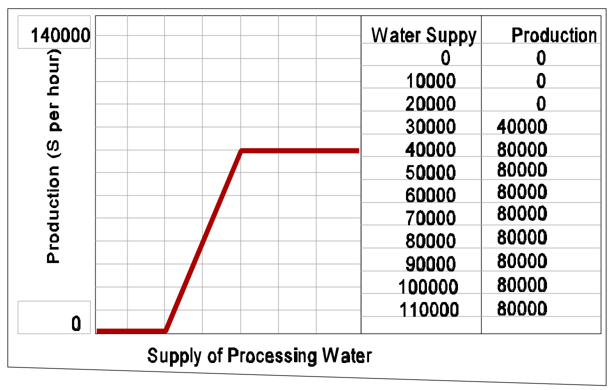


FIGURE 5. THE QUANTIFIED RELATIONSHIP BETWEEN COOLING WATER AND PRODUCTION.



● The water supply system and its relationship to stakeholders' needs is also modelled. Figure 6 shows how the supply of processing water is a function of surface water elevations at the water intake, which is in turn a function of streamflows at that point. (These relationships may have been developed by observation or separate hydraulic modelling efforts).

Figure 3 depicts the reservoir storage, inflow, release and the rules governing releases. The shared vision model now includes all the relationships necessary to determine how changes in inflows to the reservoir or reservoir releases will affect employment and deliveries.

FIGURE 6. THE RELATIONSHIP BETWEEN SYSTEM AND STAKEHOLDER WATER.

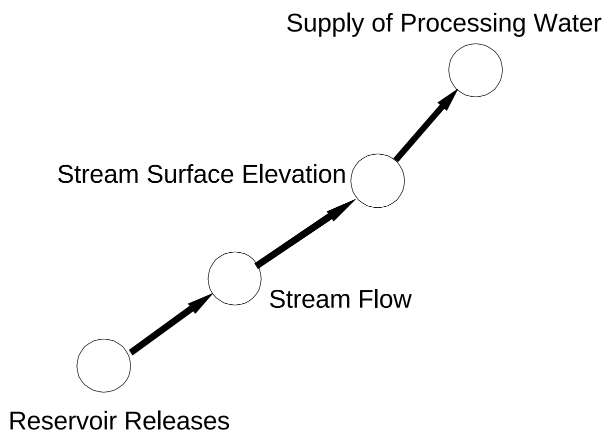
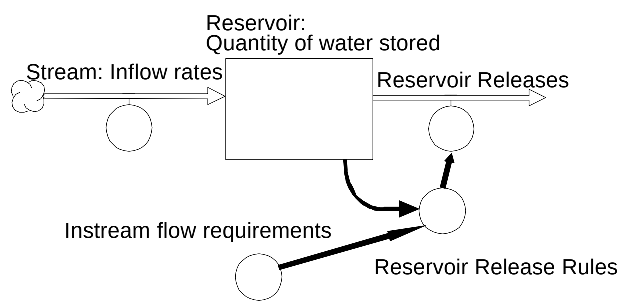


FIGURE 7. THE CENTRAL WATER SUPPLY SYSTEM.



- Performance measures should be included in the status quo model. Figure 8 shows that one performance measure, “Cumulative Production Loss” is defined based on Daily Production Loss which is in turn a function of “Production”.

Figure 9 shows the equation that quantifies daily production loss, revealed by “clicking” when the computer cursor points to the icon named “daily production loss”.

FIGURE 8. COUNTING THE NUMBER OF DAYS WITHOUT PROCESSING WATER.

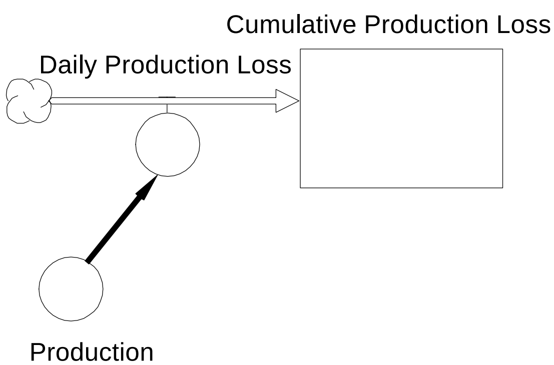
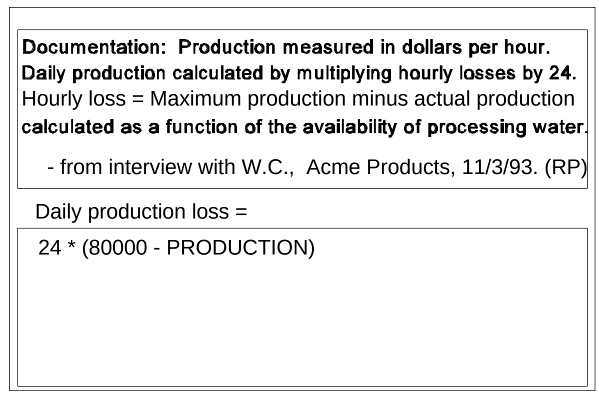


FIGURE 9. THE DEFINITION OF DAILY PRODUCTION LOSS.



SELECTING DESIGN DROUGHT(S)

In flood damage reduction studies, the expected value of future damages are estimated using a series of increasingly larger and rarer floods. In many cases, large and small floods have the same shape (defined by the onset, peak, and subsidence of high streamflows over time); only the magnitude is different. Flood magnitudes can often be characterized in terms of one parameter; streamflow. A sixty year period of stream flow records constitutes a large sample size - thousands of short duration flooding events - from which to estimate the probability that floods will exceed a given peak.

But droughts are not as easily characterized as floods. No one can predict the form of a future drought; droughts have different severities, durations, and patterns of severity. (They may be moderately severe for years or very severe for a season). In many regions, multi-year droughts are of major concern. For some interests, the deficiency of flow in a given year causes the main economic impact whereas for other interests, carryover storage can provide for one year's deficiency. The cumulative effect over several years is most important. In some forms of agriculture, farmers can reduce economic impacts of a prolonged drought by changing crops or letting fields lie fallow until the drought is over.

Because the *sequence* of events within a drought is important and at the same time beyond our ability to forecast, planners often test drought plans by using the precipitation and runoff recorded during historic droughts, either the worst on record, or the worst in recent memory.

The primary disadvantage to this approach has been the inability to estimate the probability of a similar drought occurring in the future. If the most severe droughts or floods on record are not representative of the statistical population, it is obvious that the design will become distorted (Maass, 1962).

Record low precipitation in the early and middle 1960's created a drought emergency in New England and the mid-Atlantic states. Planners had designed water systems on the drought of record, but the 1960's drought was more severe (Holmes; 1979). At the beginning of the National Drought Study, a number of well informed conference speakers stressed how improbable a *three* year drought in California would be, although that drought eventually lasted six years. The National Drought Atlas can be used to determine the rarity of historic droughts, and thus enhance planners confidence in the use of the historic drought to test drought plans. But the use of the historic drought cannot provide answers concerning the vulnerability of the region to more severe droughts or droughts with different patterns.

An alternative approach, easily accommodated by modern computer software and hardware, is to consider a variety of synthetically defined droughts, and to worry less about proving they *could* happen and worry more about the consequences if they *did* happen. This will provide additional information for the DPS team. If the impacts of drought increase precipitously for droughts greater than the drought of record, the DPS team should consider the costs and benefits of preparing plans for these severe droughts. The desire to *prove* that a sequence of low flows could happen may be expensive and time consuming. If agreement can be reached, further study of frequency can be curtailed. See Annex G, Hydrology, for more information on analyzing drought frequencies.

THE NATIONAL DROUGHT ATLAS

The National Drought Atlas is a compendium of statistics designed to help water managers and planners answer questions about the expected frequency, duration and severity of droughts. The Atlas was developed collaboratively by the Corps of Engineers, Miami University (Ohio), the National Climate Data Center (NCDC), and International Business Machines (IBM). The Atlas is based on recently refined national precipitation and streamflow data sets. The statistics were generated using a method (referred to as *l-moment analysis*) developed at IBM by J.R. Hosking and J.R. Wallis. The method permits greater confidence in estimating drought frequencies from the relatively small number of droughts for which there are precipitation and streamflow records.

The Atlas includes statistics in three categories:

- **Precipitation**. There are tables and graphs showing the percentage of normal precipitation that can be expected for a variety of durations, starting months, and frequencies for 111 "clusters" covering the contiguous 48 states. The recurrence intervals range from a 50 year dry to a 50 year wet event.

- **Streamflow**. The Atlas includes tables and graphs showing the percentage of normal streamflow that can be expected at various frequencies for durations of up to 12 months at individual gaging stations in the 48 contiguous states. The return intervals are the same as for precipitation.

- **Palmer Index**. The Atlas includes tables showing the percentage of time in the historic record that the Palmer Drought Severity Index (PDSI) fell below -3, -4, and -5. The PDSI was calculated at 1,135 precipitation stations and are displayed state by state. These are at-site sample statistics.

Annex N has more information on the Atlas, including a description of how it might be used.

SPECIALIZED COMPUTER MODELS

The evaluation of alternative drought plans requires an understanding of the relationships between precipitation, streamflow, water withdrawals, operating rules, consumptive use, water rights, return flows, and consumer responses to drought. In many regions, water managers have already developed models of one or more of these sub-systems.

The National Drought Study Report NDS-7, Water Resources Models summarizes brand name models in eight categories:

- general purpose software (such as spreadsheets)
- municipal and industrial water use forecasting
- water distribution systems (pipe networks)
- groundwater
- watershed runoff
- stream hydraulics
- river and reservoir water quality
- river and reservoir system operations

Economic models and less well known, very specialized models may be used in a DPS. Once the planning objectives have been identified, existing regional computer models that can answer questions pertinent to the planning objectives should be identified.

6

FORMULATING ALTERNATIVE PLANS

Genius is one percent inspiration and ninety-nine percent perspiration.

Thomas Alva Edison, 1932

Edison's light bulb, shining in a thought balloon, has become the image associated with the discovery of better ideas. But, as Edison's famous quotation suggests, this is not how invention works, and certainly not how new water management ideas are developed. What will prevent a DPS team from overlooking the good alternatives? In what detail should an alternative be formulated before it is evaluated? And how do group dynamics influence the formulation of alternatives? This chapter provides a conceptual framework for classifying and understanding alternatives.

WHAT IS AN ALTERNATIVE?

The status quo describes how a region would deal with drought without the help of the DPS. This scenario should include any changes that would occur over the planning period without the DPS. Conversely, anything that the DPS could change can be an alternative.

THREE TYPES OF ALTERNATIVES

Measures to reduce water shortage impacts can be categorized as strategic, tactical, or emergency. *Strategic* measures are long-term responses, such as the provision of water supply storage, or codes requiring the installation of drought resistant landscaping in new homes. They are usually established in law and supported by considerable investment. Drought responses (often called drought contingency plans) are *tactical* measures. Tactical measures are short term and deal with problems within the framework set by strategic measures. *Emergency* measures are responses to circumstances that exceeded expectations, such as droughts more intense or prolonged than any on record, or events with a very rapid onset, such as pollution of water supply, or disruption of water delivery by floods, earthquakes, and cold.

Some alternatives are on the border of two categories. While it is not important for a study team to label an alternative as being exclusively in one of these three categories, it is necessary for a team to consciously consider the relationships between the three types of measures. For example, emergency responses can be much more effective if the coordination mechanism is exercised along with the tactical drought response. And the effectiveness of some drought contingency measures may be helped or hurt by the implementation of strategic measures. Table VIII lists the three types of alternatives. Flood responses can be geared to one parameter, peak flow. However, because droughts are multi-dimensional, tactical measures may be specified in general terms during the DPS, but applied in more specific terms during a drought.

TABLE VIII. THREE TYPES OF RESPONSES TO WATER SHORTAGES.

THE THREE TYPES OF ALTERNATIVES

TYPES	EXAMPLES
Strategic measures are long-term responses. They are more likely to be established in law and supported by considerable investment.	Strategic measures include long term conservation programs, conjunctive management of surface and groundwater, assurance districts, construction of new reservoirs, changes in state law, the reassignment of water responsibilities among water agencies, and increasing water prices or adjusting rate schedules.
Tactical measures are short term responses planned within a strategic framework	Response measures (conservation or supply); triggers for those responses; methods of collaboration on decisions; new decision processes; new ways of dealing with and involving the public.
Emergency measures are responses to unexpected circumstances.	Emergency drought responses may be required when a drought is much more severe or long lasting than had been thought possible. Emergency measures might include plant closings or the condemnation of water rights. A drought planning team might also want to consider emergency responses to water shortages not caused by drought, such as a city's response to an oil spill which will require the closure of its main water intakes, or an earthquake which destroys water supply lines.

INITIAL LIST OF ALTERNATIVES

An initial list of alternatives should be developed by brainstorming (see page 16) early in the DPS, but after first statements of problems and planning objectives have been developed. Brainstorming can be supplemented with the generic alternatives listed in Table IX, page 49. Brainstorming is apt to include a number of preconceived alternatives to the status quo, some advanced by the stakeholders it will benefit. DPS teams should focus on the ends, not the means, and should avoid using the DPS to justify any group's idea. Chapter 7 describes how these initial ideas can be evaluated quickly so that only the most promising alternates are developed in detail.

Drought response plans are composed of tactical measures. Tactical plans can often greatly reduce a region's vulnerability to drought, and are usually easier to implement than strategic alternatives.

Elements of a Tactical Drought Plan

A **drought response plan** is a series of tactical measures that will be implemented at the time of the drought to reduce the residual drought vulnerability left by strategic measures.

A tactical response plan should have the following elements:

- triggers
- forecasts
- monitoring
- enforcement
- public affairs strategy
- management measures
- coordination mechanism

An overview of each element follows. A discussion of how strategic and tactical measures can be integrated begins on page 47.

Triggers. Because a drought does not begin with a climatic event, like a flood, its onset may be difficult for stakeholders to recognize. A drought indicator is an objective measure of the system status that can help agencies identify the onset, increasing or decreasing severity, and conclusion of a drought.

Plans generally call for certain measures to be initiated when a drought indicator reaches a predefined level, a *trigger*. Trigger levels can be refined through computer modelling to strike an acceptable balance between the frequency of drought declarations and the effectiveness of an early response. The nature of the indicator and the level at which responses are triggered should be selected to reduce economic and environmental consequences.

Forecasts. If water managers knew in advance how long a drought would last, how severe it would be, and how effective demand management measures would be, they could optimize the magnitude, timing and duration of the response measures to minimize the negative impacts to stakeholders. Because these things generally cannot be known until the drought is over, managers use forecasting techniques to estimate supply and demand functions.

Case study experience during the National Drought Study suggested three ways that DPS teams might be able to improve the usefulness of forecasts. First, the forecasts should be used as inputs to the shared vision model to evaluate the probable impacts of alternative measures during a drought. Second, the agencies in a DPS study should pool forecasting sources and data analysis during the DPS to provide the most consistent and complete basis for individual agency responses. Third, public information specialists should discuss the form of the forecast information with technical specialists. The media and the public will insist on simply stated predictions, and it will take a deliberate effort by technicians and public information specialists to develop language that is simple and meaningful (NDS-5). The team may need to seek new sources of forecast data. The National Weather Service and the U.S. Geological Survey are the prime sources nationwide for forecast data, and the Soil Conservation Service’s cooperative snow survey is an important source in 11 western states. The Corps of Engineers, the Bureau of Reclamation, and most states also have programs to collect or process forecast data.

Demand forecasts may also be important. Municipal consumers will greatly reduce water use if they are convinced that the drought is a real threat (NDS-5). But the percent reduction is difficult to predict unless a city has recent experience or is using a sophisticated disaggregated water use forecasting model.

Monitoring. Monitoring mechanisms must be used to determine if the drought response plan is having its intended effect. In the Seattle drought of 1992, the amount of water consumed was published daily in a local newspaper.

Enforcement. Demand reduction programs must be enforced if public support for them is to be maintained (AWWA, 1992). Enforcement rules can be codified in city, county, or state ordinances. Violators will often be turned in by water users who are complying, but in some cases, cities have used "drought police" to enforce demand reduction ordinances. Scofflaws may be issued warnings with educational pamphlets, or fined.

Public Affairs Strategy. The phrase *public involvement* has generally been used to refer to efforts that include the public in planning, whereas *public relations* is more often used to describe the methods an organization uses to promote a favorable image with the public. *Public information or affairs* is somewhere in the middle, but it is the public affairs staff that should communicate information to the public during a drought.

Previous droughts and public affairs experience in other areas have shown the worth of having a public affairs strategy developed by a team of water and public affairs specialists (Opitz, 1989). The agreement to use the collaborative DPS decision making processes during a drought can help avoid (but does not guarantee) the communication of confusing and discordant information to the public. The public will want to know the answers to the most fundamental questions in the most straightforward terms: "Are we in a drought?", "How bad is it?", "How does this affect me?", and "When will it be over?" (NDS-5). In a region with multiple water supply systems, people may live in a community with no drought problems and work in another that must impose water use restrictions. The media are not drought experts and may not have time to learn what they need to know during a drought. This problem can be reduced by inviting the media, especially meteorologists and science reporters, to demonstration workshops that show highlights from virtual droughts (see page 65). More information on public affairs is available in Annex I.

Management measures. A variety of tactical response measures is listed in Table IX. The most common are discussed below.

- **Municipal and industrial demand modification**. Most major cities in the United States have instituted some form of strategic demand modification programs, and nearly all rely on short term demand modification to address temporary, drought induced shortfalls. In some communities, due to the difficulty of finding new sources and the general environmental opposition to new dams, demand management alternatives must be exhausted before new supply sources are tapped. The term *water conservation* is generally used to describe strategic demand management measures, and *curtailment* to refer to tactical measures. Specific measures include public information campaigns, changes in outdoor landscaping practices, changes in the price of water, regulations and incentives that increase the use of more efficient water fixtures, prohibitions on certain uses, and growth management. The use of water conservation has become more widespread because it can be the least expensive way to accommodate new demands. It can also reduce the costs of meeting stable demands by reducing long and short term energy, water treatment and wastewater treatment costs.

Water conservation may paradoxically increase drought vulnerability. In the Boston area, long term water conservation has reduced not only *per capita*, but total water use (NDS-10 and 12). At the same time, the water supply storage system can store several years of normal inflows. As a result, conservation allows higher average reservoir storage levels, and reduces drought vulnerability.

However, the Boston case is atypical. Absent multi-year storage, water saved from long term conservation may only be conserved for that year. When droughts do occur, storage will be about the same and the percent reduction in water use possible from curtailment will be less.

The question of whether and to what degree water conservation and drought vulnerability are interdependent can be answered using a system analysis such as the Massachusetts Water Supply Authority's "Trigger Planning", a system of data and models built around a shared vision model (NDS-12).

- **Modification of other demands.** Farmers adapt to market trends and water availability before planting, but after planting have a limited ability to curtail water use during a drought (NDS-5).

Hydropower production may or may not reduce the availability of water for other critical needs. Hydropower production can be replaced by thermal power during droughts, but at a financial cost and with a potential impact on air quality.

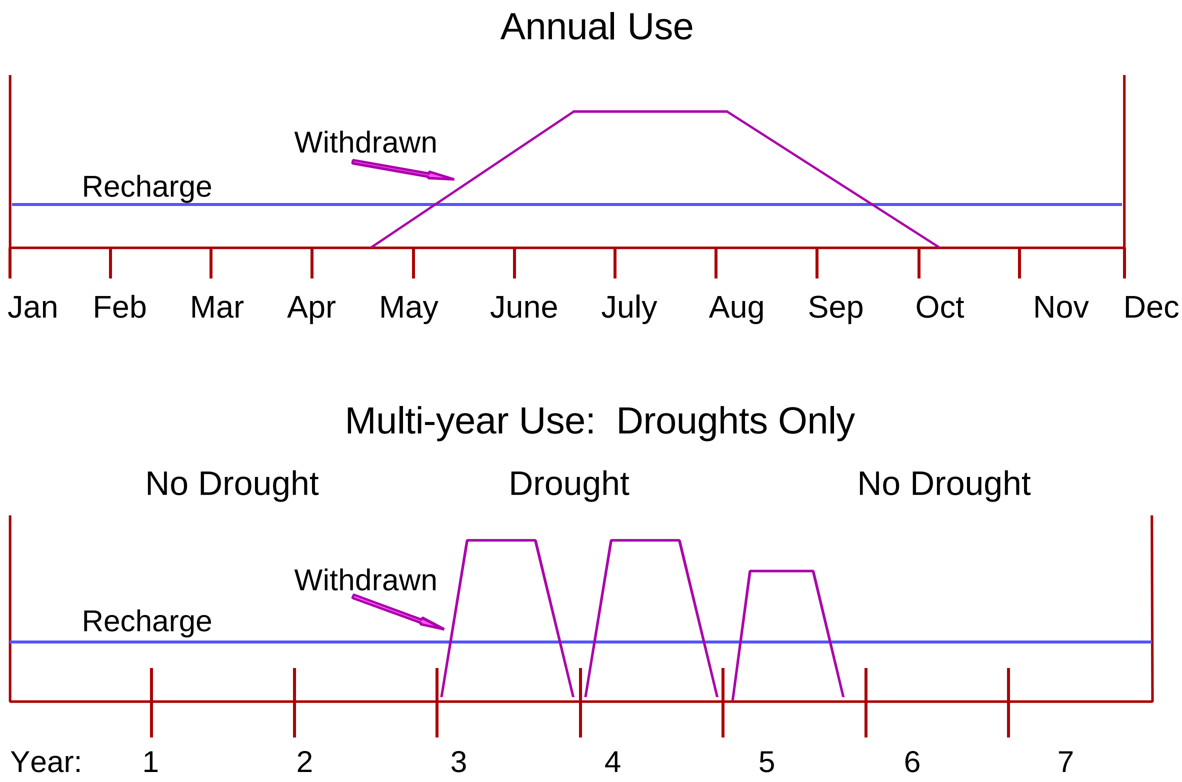
Shippers can light-load barges if normal channel depths are not available, but this increases shipping costs.

In-stream environmental water needs are generally set at threshold levels, so further reductions will generally have environmental effects (NDS-5). However, in some cases (such as the Kanawha River DPS), existing instream flow requirements may not reflect biological needs because of reductions in effluents since the standard was established. Flat water recreation may suffer from a decrease in demand during drought because of aesthetics (mud flats replace shoreline), but the visitors that do come may be able to be accommodated with boat ramp extensions and dock modifications. Whitewater rafters can use a greater number of smaller rafts.

- **Conjunctive use**. Although surface and ground water supplies have usually been developed separately, the increasing difficulty in finding new sources of water supply is causing increased interest in conjunctive use, or joint development of ground and surface sources. The potential for increasing safe yield by this approach is considerable.

In large, deep aquifers, withdrawals from groundwater can be increased during drought provided that proper arrangements are made with respect to safe yields.

FIGURE 10. CONJUNCTIVE USE OF GROUNDWATER FOR DROUGHT



The possibilities of conjunctive use are illustrated in Figure 10. The upper diagram shows use of underground storage for annual periods of deficiency, resulting either because of low flows, poor quality in streams, or of high seasonal water use. The lower diagram shows the potential for saving the limited potential of underground storage to cope with shortages during droughts only. A more sophisticated method of using underground storage is by aquifer recharge and recovery. This is often done in California, where spring runoff and even reclaimed wastewater can be used for recharge.

Despite its potential, conjunctive use arrangements have not been exploited as fully as they could be. There are many reasons for this. Many groundwater basins have neither been quantified nor allocated among users. Preservation of water quality during the recharge of aquifers is critical, and requires coordination between regulatory and supply management agencies. Perhaps most significantly, conjunctive management is discouraged by the lack of definition of rights to recapture surface water stored in underground basins (ACIR, 1991).

Operational coordination. As the difficulty of developing additional supply storage increases, the advantages of increasing safe yield through the coordinated operation of multiple water systems has become more appealing. Such possibilities are not apt to be among the first to be suggested. In fact, administrators and operators of water systems are usually very reluctant to consider such an alternative, which would deprive each system of a part of its operating autonomy in the interest of overall efficiency and total aggregate safe yield. However, as the other disadvantages of alternatives are evaluated, intersystem operational coordination may become the only practical answer.

Depending on the circumstances, operational coordination of the facilities of two or more water systems can usually provide a safe yield of water greater than the total available. This can happen if the systems are operated separately, each maximizing its own financial return. The classic example is in the Potomac River Basin. Coordinated operation of the upstream and downstream facilities of the various public and private utilities can produce a total safe yield 45% higher than that of the same utilities operated separately (Eastman, 1986). In other river basins such large savings are not usually possible. However, a study made for the State of New Jersey for public and private systems on the Passaic River showed that a 25% increase in total safe yield could be gained by an integrated operational control (David, 1989). On a smaller scale, regional use of reservoir systems is being developed in Texas.

Staging management measures. Drought response measures come at a cost, so their imposition should come in stages commensurate with the seriousness of the threat of drought damages. Early invocation of moderate demand reduction measures can delay or prevent the implementation of more restrictive responses. Still, the decision to intervene earlier in a drought is a decision to increase the number of drought declarations over time. Again, position analysis using the shared vision model can help the DPS team develop general relationships between triggers and the degree of drought response measures. The model should also be used *during* a drought to reanalyze the benefits, costs and risks of shifting to the next response stage too soon or too late.

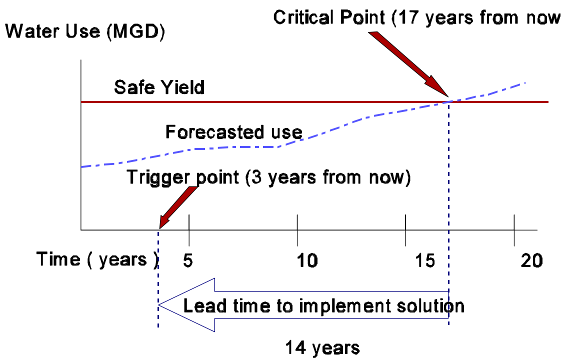
INTEGRATING STRATEGIC AND TACTICAL PLANS

The DPS method of preparing for drought is based on sound principles for water resources planning and management for all meteorological conditions. The frequency of drought declarations, and the effectiveness of tactical and strategic measures are interdependent.

As part of the National Drought Study, the Massachusetts Water Resources Authority (MWRA), the Water Supply Citizens Advisory Committee (WSCAC), and the New England division of the Corps of Engineers collaborated on a project to relate strategic and tactical water resources measures. Collectively referred to as *trigger planning*, it is an attempt at what might be called “just in time” water supply enhancement; an operational system that can reduce economic and environmental investments in supply and demand measures while maintaining necessary water supply reliability.

Droughts in the 1960's in New England and the mid-Atlantic and in the 1980's and 90's in Atlanta, California, and Seattle brought renewed public interest and support for strategic changes to balance water supply and demand. Even if studies of strategic measures begin before water shortages occur, there is no assurance that the study will solve the problem. Supporters and

FIGURE 11. TRIGGER PLANNING KEEPS ECONOMIC AND ENVIRONMENTAL INVESTMENTS IN WATER SUPPLY LOW WHILE AVOIDING CATASTROPHIC WATER SUPPLY FAILURES.



opponents of various supply and demand management alternatives may contest each others positions in planning, regulatory, legislative and judicial forums. If theplanning recommendations are rejected in a permitting process or judicial review, more time will be required to develop an acceptable alternative plan to an implementable level of detail.

Trigger planning is a new approach to urban water management. MWRA's trigger planning system is built from traditional data sources and models, but with three additional and unusual building blocks:

- the close collaboration of WSCAC and MWRA. MWRA pays for two full-time staff positions and office expenses for WSCAC. WSCAC has complete online access to MWRA's computer files. WSCAC is respected for its independence and support for environmental and fiscal values. However, its closeness to MWRA allows it to contribute earlier in the planning process, before an agency position has been taken and while there is time and money to change plans.

- the use of a shared vision model

- the use of IWR-MAIN 6.0 to develop water use forecasts that can reflect a variety of potential water conservation plans.

The resulting system allows WSCAC and MWRA to continuously monitor water use forecasts, present use, safe yield, and cost effectiveness. The point in the future when water use is forecasted to exceed the safe yield of the system is called a "critical point". Estimates can be made of the amount of time and the separable increments for implementing a solution that will avoid water supply shortfalls, so that the date and minimum requirement of the first step in the solution can be identified. The date for first required action is called the "trigger point". Because water use forecasts can be easily adjusted as new population and employment forecasts become available, trigger points for later stages of implementation can be kept current. If new forecasts call for slower growth, trigger points are moved into the future and implementation of the next step is delayed.

Trigger planning is expected to reduce the risk of water supply shortfall and the risk of over-investment of environmental and economic resources to create an unnecessarily generous supply.

In addition, the family of models integrates long term and drought water management, allowing estimation of the effect of long-term conservation measures on water curtailment programs used during drought.

After the difficulties of implementing the more obvious alternatives are explored (Chapters 8 and 9), it may be found that some of the other alternatives may have to be reconsidered more seriously.

TABLE IX. A LIST OF TYPICAL STRATEGIC AND TACTICAL MEASURES.

	STRATEGIC	TACTICAL
Supply Alternatives		
New storage	✓	
Reallocation of supplies	✓	
New system interconnections	✓	
Desalinization, importation by barge, reuse	✓	✓
Operational Changes		
Conjunctive use management	✓	✓
Water banking	✓	
Long-term changes in reservoir release rules	✓	
Conditional reservoir operation and in-steam flows		✓
Water marketing	✓	✓
Institutional changes	✓	
Legal changes	✓	
Operational coordination between systems	✓	✓
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		✓
Environmental and Water Quality Changes		
Reductions in required low flows		✓
Alternative means of achieving water quality		✓

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7 EVALUATING ALTERNATIVES

Once the objective has been determined, our methodology leads to the selection of that combination of structures, levels of development for different water uses, and operating procedures that will best achieve the objective.

- Arthur Maass (Design of Water Resources Systems, 1962)

The methods of water system design developed by an interdisciplinary team at Harvard University are best known for their influence on the study of the feasibility of new water projects. However, as the quotation from Professor Maass, the principal author of Design of Water Resource Systems shows, the concept of objective based design can be applied to operating procedures as well. In this step, the team compares proposed alternatives against the status quo, measuring how well they meet the objectives developed in step 2. The team will eliminate or redesign alternatives that do not measure up, until they are ready to recommend a plan to decision makers. This chapter describes how to conduct such an evaluation.

Evaluation is the process of estimating how well alternatives perform in the five categories of measurement described in Chapter 4. In each category, the alternatives are measured against the common baseline of the status quo. In order to make the best use of study resources and be responsive to those who have suggested alternatives to the status quo, the evaluation process should begin with brief, documented reviews of many alternatives and end with more thorough reviews of just a few alternatives.

INITIAL SCREENING OF ALTERNATIVES

The preliminary screening of alternative plans can be done by determining whether they address the planning objectives, how they perform (according to the accepted measures of performance), and how well they satisfy decision makers' criteria. Plans that meet these preliminary tests can then be evaluated according to their economic, social and environmental impacts.

The P&G list four characteristics of good plans. These characteristics are general enough that they are appropriate for federal or non-federal planning efforts:

- ***completeness*** (all the elements required to make the plan work are included in the plan);
- ***effectiveness*** (the alternative addresses the planning objectives);
- ***acceptability*** (the plan satisfies decision criteria and does not violate planning constraints); and
- ***efficiency*** (the ratio of plan outputs to inputs).

Alternatives should first be examined to see if they are complete. Completeness does not imply a high degree of detail; at this point, alternatives should *not* be developed in detail. Completeness simply means that the basic components have been identified.

TABLE X. AN INITIAL SCREENING OF ALTERNATIVES

Alternative Plan Number	Is the plan Complete?	Acceptability		Effectiveness
		Meets decision criteria?	Violates constraints?	Meets planning objectives?
1	No	N/A	N/A	N/A
2	Yes	No	Yes	Does not meet water quality objective.
3	Yes	Maybe	Yes	Does not increase hydropower production
4	Yes	Yes	No	Yes
...				
11	Yes	Yes	No	Yes
12	Yes	Yes	No	Should greatly help M&I, may hurt river recreation

The initial screening focuses on the characteristics that are necessary and more easily assessed: completeness and acceptability. An incomplete alternative can be reformulated and assessed again. This initial assessment takes place before any alternatives are modeled, so neither the performance or effects of alternatives can be estimated at this stage.

For example, an alternative that calls for the joint operation of independent water systems is incomplete if it fails to include the construction of the necessary physical connection between systems.

The initial screening should emphasize effectiveness and acceptability. As Table X illustrates, this can be done using decision criteria, planning objectives and constraints. The goal of the initial screening is to eliminate some alternatives, and develop a ranking of the remaining alternatives. The process of ranking may help in the continuing effort to communicate and clarify objectives and criteria. The initial screening permits the focusing of study resources on the detailed evaluation of the most promising alternatives.

MODELING

Each of the alternatives being seriously considered should now be modeled. In some cases, teams may decide that each alternative should be represented by a separate model (a modification of the status quo model saved with a different file name). In other cases, teams may decide that alternatives can be more effectively represented by internal "switches" in the status quo model which effects the desired change in water management procedures. The models provide the plan performance and outputs required for detailed evaluation.

Using the model, the next level of evaluation can be on the basis of *performance measures*. For example, the model can be used to estimate how much more frequently would a city have to impose curtailment under an alternative than under the status quo. (See page 38 for a display of how these performance measures would be modeled, and page 57 to see what the outputs for an alternative might look like.)

ESTIMATING EFFECTS

Sometimes an evaluation using just performance measures is enough. If operational changes can be made that benefit many users and hurt none (including the environment), and the value of the benefits clearly outweigh the administrative costs of instituting the changes, then an evaluation of the economic and social effects of each alternative is unnecessary. But what if there is an alternative that benefits some users and hurts others? Or what if an alternative helps everyone, but has a significant financial cost? In those cases, an evaluation of the economic, environmental, and social effects of the alternatives is the only way to determine which alternative best addresses the goals and decision criteria.

Economic benefits can be defined in market transactions as the sum of producer and consumer surplus. Both are based on the volume of transaction(s) at a price. Consumer surplus is the difference between what consumers would have been willing to pay and what they did pay; producer surplus is the difference between what a producer would have been willing to sell for and the actual revenue received.

But most water transactions are not based on market forces; they are typically based on past use and regulation. Hence, the calculation of changes in consumer and producer surpluses among five or six competing uses cannot be done straightforwardly. The application of economic principles to drought is fraught with conceptual difficulties. There are some generally accepted methods of estimating these benefits, however, and these are explained in Annex F.

An analysis of the economic impacts of droughts creates a rational basis for making monetary tradeoffs to reduce the net impact of a drought. These tradeoffs may be made between financial (benefit/cost ratio) or opportunity costs (the benefit lost because water was shifted from one use to another).

Like all components of a DPS, the extent of the economic analysis is constrained by study budgets and schedules, and must reflect how important economic effects will be to decision makers.

If an alternative includes changes in the operation of a federal project, then an evaluation of NED may be necessary. In general, there will be greater interest in regional economic development (RED) benefits (regional efficiency) and impacts (distribution of benefits, employment).

Environmental and social impacts of the various alternatives should be evaluated quantitatively as far as practicable. This means evaluation in terms such as the number of fish killed or criteria of water quality affected by a given stream flow. This may be very difficult to estimate.

There is considerable information concerning the general relationship between the preservation of aquatic habitat for different species and water characteristics such as flow velocity, stage, temperature, wetted area, and concentration of dissolved oxygen (Arnette, 1976). Fish populations in a given year, however, may be a function of a sequence of events within the river basin (Miller, 1976) as well as factors unrelated to water management, such as the number of anadromous fish caught off shore (NDS-5). The effects of droughts that last as long as the entire reproductive period of a species are also not well known (NDS-5). The U.S. Fish and Wildlife Service (Department of the Interior) and the National Marine Fisheries Service (Department of Commerce) should be consulted to determine if there are threatened or endangered species in the study area. If so, the DPS team should identify *constraints* on operating policies which would affect those species. Section 7 of the Endangered Species Act of 1973 (Public Law 93-205) requires all Federal agencies to seek to conserve threatened and endangered species, and to insure that the actions of Federal agencies do not jeopardize the continued existence of any threatened or endangered species or result in the destruction or adverse modification of the habitat determined by the Secretaries of Interior or Commerce to be critical unless an exemption has been granted by the Endangered Species Committee (EP 1165-2-1).

TRADEOFFS ACROSS ACCOUNTS

The discussion of accounts on page 30 explains their usefulness in organizing the effects of an alternative in a meaningful way. By definition, there can be no pre-existing rate of trade between effects from different accounts. That does not mean that society assigns an infinitely large or small economic value to social and environmental impacts. It does mean that trading among the accounts will be difficult. If tradeoffs must be made across accounts, they will be negotiated and constrained by law and politics.

However, cost-effectiveness frontiers and incremental (marginal) cost analysis can be used to minimize the costs associated with producing a given level of social or environmental impacts, and to associate costs and impacts as the basis for negotiation. The goal of these methods is to reveal how much environmental output is generated per incremental dollar spent per alternative. A description of how an incremental cost analysis is done is shown on page 56 (Hansen).

Risk and Uncertainty. The definitions of these terms as they are applied to water resources management have changed a little over time. *Risk* refers to some negative consequence with an associated probability, even if that probability is difficult to calculate. Risk in water resources management has until recently been defined as the product of the consequence of events multiplied by the probability of the events, that is to say, as an expected value of damages (Guidelines For Risk, 1992). The classic definition of *uncertainty* involved those unknowns that could not be expressed in probablistic terms.

In flood damage reduction studies, risk which is an expected value of the damage from extreme, but rare floods can be compared to annual or present day costs to determine if it would be cost effective to reduce residual flood damages even further by increasing the size of the flood control project. In strategic water supply studies, the "rare, large event" is the drought, and the risk associated with any strategic supply plan is the product of the expected consequences of future droughts times their probability.

But research and experience has shown that people react differently to the risks of a low probability, high consequence events (a 500 year flood, for example) and a high probability, low consequence events (a 2 year flood), even though they may have the same expected value (Guidebook for Risk Perception and Communication, 1993). Thus a more useful definition of risk has come into use, that does not multiply damage by probability: risk is the expression an undesirable consequence in terms of the probability of it happening.

The concept of risk in tactical drought contingency plans has much in common with the risks associated with flood warning systems that are used to minimize damage from floods larger than the design flood. Risks in drought management include:

> the risk that a very severe drought will cause a catastrophe;
>
> risk that the drought response plan will be triggered too often (risking reduced effectiveness of public participation in subsequent droughts) or too late (eliminating water savings that would have been possible had the response been initiated sooner).

Both of these risks can be assessed using the shared vision model. No simple quantification, however, will generally be possible, because of the various combinations of severities and durations of droughts. Nonetheless, the use of the Drought Atlas (see Annex G) and simulations with the shared vision model can develop a better informed sense of the risk that can be more clearly communicated to decision makers and elected officials.

DECISION SUPPORT SOFTWARE

There is a sound theoretical base and a variety of computer software packages for modeling decision processes. The software packages create mathematical models that require a listing and ranking or weighting of the decision criteria. Use of decision support software may help:

- focus attention on the criteria during the evaluation of alternatives;

- the DPS team think about the relative importance of the criteria, and degrees of fulfillment of each criterion;

- document the evaluation of alternatives leading to the selection of the recommended plan.

These packages can enrich a DPS team's understanding of the process that will be used when regional leaders decide whether to accept their recommendations. DPS teams should consider using sociologists, political scientists, conflict resolution specialists, or other professionals with experience in this area.

The evaluation of alternatives should lead to tentative recommendations from the DPS team. The next chapter describes how to secure the commitment of decision makers to a plan.

TABLE XI. THE COSTS PER UNIT OF OUTPUT (FOR EXAMPLE, ACRES OF WETLAND)

Plan Element	Units of Output	Total Cost
A	80	$2,000
B	100	$2,600
C	110	$3,400
D	120	$3,600
E	140	$7,000

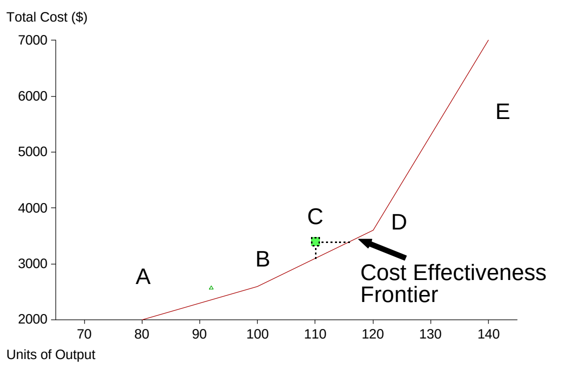


FIGURE 11. THE COST EFFECTIVENESS FRONTIER.

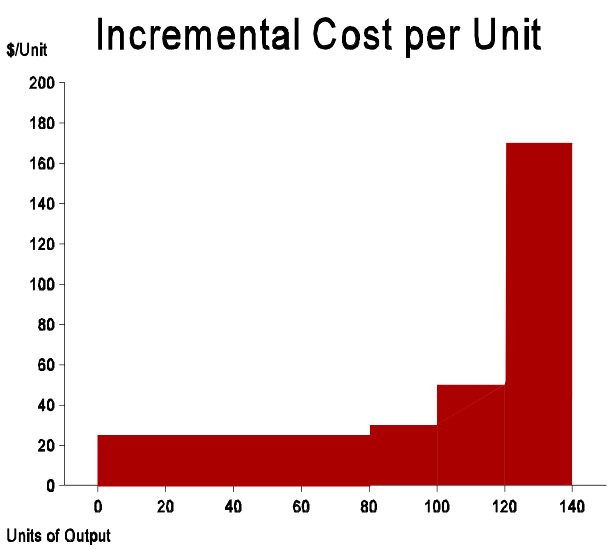


FIGURE 12. IT COSTS $25 PER UNIT TO INCREASE OUTPUTS FROM 0 TO 80 UNITS, BUT $50 PER UNIT TO GO FROM 100 TO 120 UNITS.

Steps in an Incremental Cost Analysis

These four steps offer a simplified example of how incremental cost analysis is done.

1. State the planning objectives in such a way that a metric for environmental or social outputs can be used relative to these objectives. For example, the team might want to "increase wetland functions" compared to the status quo. One metric might be the number of wetted acres added (over the status quo) by Alternatives A-E.

2. Create a table that shows the costs and outputs of each alternative (Table XI).

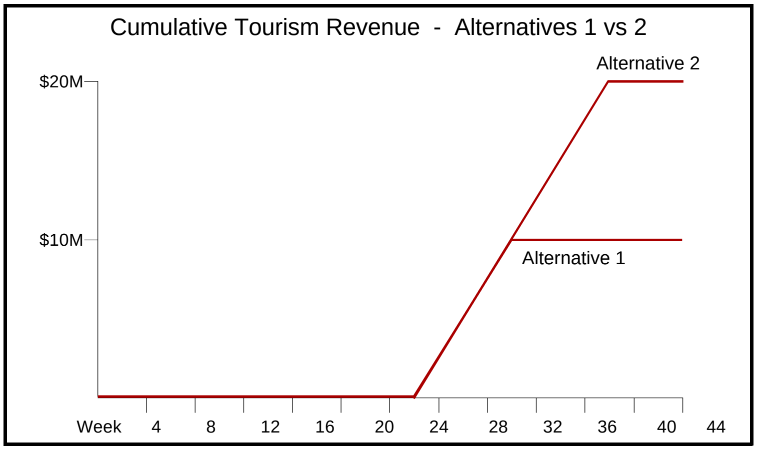
3. Plot a cost-effectiveness frontier, as shown in Figure 11, that corresponds to the data in Table XI by connecting (or smoothing) the most cost-effective points. Alternative "C" is above the frontier because it offers less environmental output per dollar than the B-D frontier suggests is possible. The frontier can be useful as a screening mechanism because no plan above the frontier plan is as cost-efficient in producing a given output as the plan on the frontier at the same output.

4. Graph the incremental cost per unit (Change in cost ÷ change in output) as shown in Figure 12. This graph gives a clear picture of how costs increase incrementally as greater outputs are pursued. The graph simply displays some of the information included in Table XI more clearly, and by doing so, may help teams decide what level of output is economically acceptable.

Combinations of measures can be compared by adding a few more steps. (Hansen, 1993).

TABLE XII. A MORE DETAILED EVALUATION OF ALTERNATIVES.

The table below illustrates how a shared vision model can be used to analyze and display the effects of 2 alternative drought plans that have passed a preliminary screening (they both meet the planning objectives and violate no constraints). The comparison is based on a simulation of the drought of record, a one year period. When compared to the status quo, the two alternatives both reduce the number of days of curtailment of M&I and recreation, and cause no additional reduction in hydropower production. (Under the status quo, it would cost $12,000,000 to replace the hydropower lost during this year long drought, and that remains true under these two alternatives.) Alternative 2 permits more rafting days than Alternative 1, but also requires a longer period of urban water use curtailment. Which should be sacrificed? The measurement and comparison of the effects of each alternative provides valuable information in such cases.

	Standard of comparison	Status Quo	Alternative 1	Alternative 2
PLANNING OBJECTIVES	Improve M&I service		Yes	Yes
	Increase rafting		Yes	Yes
	Maintain hydropower		Yes	Yes
MEASURES OF PERFORMANCE	Days of rationing	100	60	75
	Number of rafting days	0	56	112
	Hydropower produced	123 MW	123MW	123MW
EFFECTS	Recreation benefits over status quo (NED)		$23,000,000	$56,000,000
	Increase in tourism revenue over the status quo (RED).			
	M&I utility revenue shortfall	$10,000,000	$6,000,000	$7,500,000

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8 INSTITUTIONALIZING THE PLAN

The danger in not formalizing the plan is that a change in political or administrative leadership may lead to decay of the plan's infrastructure. It must be emphasized that political interest in drought quickly wanes when the crisis is over.

- Donald A. Wilhite (Drought Assessment, 1993)

The DPS team constitutes a new, integrated community that more closely mirrors the integrated nature of the problemshed. But as the team's planning work nears completion, it must find a way to institutionalize the integrated problem solving approach so that it can outlive the DPS for use in the next drought. To do that, decision makers must approve the recommendations of the DPS team and agree to change the institutions of the entities they manage to reflect that agreement. This chapter offers some ways to negotiate that approval.

The findings of the DPS are presented as a written report; but the most important product of the DPS is the new *process* of water management. A successful DPS is institutionalized by agreement among the responsible agencies to act according to the findings of the DPS.

In this step, the DPS team recommends a plan to decision makers, specifies necessary changes in laws and regulations, completes environmental assessments or impact statements, and facilitates negotiations on the agreement(s) decision makers must approve to institutionalize the new processes.

RECOMMENDING A PLAN

The final selection process must include negotiations, bearing in mind that what is most important is not the personal opinion of the individuals around the table but general public opinion and the political influence of the organizations which these individuals represent.

To help secure commitment from decision makers, the DPS team should organize evaluation data and prepare presentations in such a way that the "bottom line" is clear to decision makers. These decision makers will not have the benefit of immersion in the evaluation process with the shared vision model that the DPS team members enjoyed.

A process which was used in the plan selection workshop in the Kanawha River DPS proved to be very useful for building confidence in the selection process. As part of the workshop, a "Decision Matrix" was prepared, (Table XIII), which illustrated comparison of impacts, including both economic and non-economic. First, the distinct features of each plan were reviewed and their shared vision model was used to estimate how each alternative would affect the interests of stakeholders. Next, the workshop facilitator, using a table showing each of the planning objectives as column headings and each of the alternatives as rows, scored each alternative from "---" (very negative impact) to "+++" (very positive) for each objective. As he did so, workshop participants were encouraged to debate the rating based on the model outputs, and to assign their own ratings on a similar blank score sheet each had received. These simplified ratings merged the performance of the plan on the two design droughts that had been considered, and took account of all the measures for each objective.

The scoring showed that two alternatives improved the performance of the system in several objective categories, and matched the performance of the status quo in all other objectives. The analysis showed that Plans 4 and 5 helped water quality, rafting, and lake recreation, and did not affect hydropower or navigation. Plan 2 helped rafters, but hurt lake recreation; Plan 3 did just the opposite. Because plans 4 and 5 were not mutually exclusive, the workshop participants agreed that a plan that combined the advantages of both should be used during the next drought.

In many cases, the choice will not be as clear. In those cases, Circle B and C participants can enter into a process of negotiation supported by the shared vision model and evaluation data. These negotiations are most likely to be successful if the participants have been given specific authority to make agreements for decision makers. Otherwise, no participant will know if further concessions will be needed. Further modifications to alternatives or new conditions for their use may be considered to develop a consensus on a recommendation. It may be useful to break into smaller groups to determine if the small groups could support an alternative plan before negotiating in plenary sessions.

When stakeholders believe that no alternative reduces impacts enough, the options that remain are:

- to accept the fact that, even with the best plan, impacts of a severe drought will be very damaging;

- to decide that the interests of the region would be best protected by pushing for a long-range solution, either new infrastructure or one of the non-structural long-range alternatives;

- to agree to pursue the plan that helps most stakeholders;

- to agree to pursue the plan that helps most stakeholders, but with payments to those who are hurt;

- to accept a plan in principle, but agree to proceed with it during a drought only if possible losses by some stakeholders do not materialize (because of changed conditions or uncertainties about the estimates of harm).

CHANGES IN LAWS AND REGULATIONS

If the recommended plan includes changes in existing laws, regulations, or structures, then the team should develop a plan to effect those changes. The team should be mindful of the fact that these changes will probably not occur until sometime after the DPS is complete, and must be budgeted and staffed separately. Now the early effort to include those involved in long term management processes (see page 18) will pay dividends.

As the choice between alternatives narrows, it is desirable to make final checks upon cost, financing, legality, and public acceptability. The adoption of the plan will be manifested by publication of the report; but the effectiveness of the plan depends upon agreement by the responsible agencies to implement it.

ENVIRONMENTAL REVIEW

If the recommended plan involves changes in the operation of federal water projects, the National Environmental Policy Act (NEPA) requires an environmental review. The minimum required response is an Environmental Assessment (EA) and Finding of No Significant Impact (FONSI). The DPS should have involved environmental representatives and investigated potential environmental impacts, making it easy, fast and inexpensive to produce the formal EA and FONSI. If there are significant impacts, an Environmental Impact Statement must be prepared and circulated for approval.

NEGOTIATING CLOSURE

The connections from Circle A, B, and C to Circle D must now be exercised. The decision makers who will sign the agreement to institutionalize the recommended plan must be approached and any remaining conditions for their signing negotiated.

The DPS team may decide to present their process and findings to decision makers in a final workshop. The purpose of this demonstration workshop is to showcase the collaborative analytic efforts and the support for the recommended plan among those most affected by it.

THE AGREEMENT

Institutionalization requires written agreement to act according to the findings of the DPS. Operating policies (reservoir or pump station operating plans, or individual drought contingency plans) may have to be revised within the collaborating agencies near or after the completion of the DPS.

Implementation is greatly simplified if the area of concern lies in a single state, or if it is encompassed by a River Basin Commission, with responsibilities related to drought. Otherwise, interstate agreements or memoranda of understanding will be necessary.

Partnering agreements, which have been used by the Corps of Engineers to improve the quality and productivity of the Corps construction contracts, may be helpful in publicizing the intent of the agencies to act according the findings and spirit of the DPS. A partnering agreement does not legally bind the signers to a set of actions, but simply expresses the mutual advantage desire in acting in a particular collaborative fashion. An example of a partnering agreement is shown in Figure 13. A partnering agreement can:

- establish a continuing collaborative process;
- support the maintenance and use of the shared vision model;
- name those involved in drought committees;
- establish legal bounds on the agreement;
- specify when Virtual Drought Exercises will be held.

TABLE XIII. FINAL PRESENTATIONS TO DECISION MAKERS SHOULD MAKE THE RESULTS AS CLEAR AS POSSIBLE.

*Simple matrices like this can be used to starkly and clearly portray the DPS team evaluation process to decision makers **after** the team has used more sophisticated and quantitative analyses to select a recommended plan. This table made it clear to the participants of the Kanawha River DPS workshop that delaying the start of water quality releases and varying the amounts of those releases hurt no one and benefited many. Even water quality was improved, since dissolved oxygen levels were high at the beginning of a drought, and delaying augmentation releases conserved water that could be released later in the summer when dissolved oxygen levels were lower.*

Objective→ Alternative ↓	Increase the quality of river water in the Kanawha River basin during drought	Increase the reliability and value of the Gauley River whitewater rafting experience during drought	Increase the reliability of lake recreation in the Kanawha River Basin during drought	Increase the reliability of hydropower generation in the Kanawha River basin during drought	Increase the reliability of navigation on the Kanawha River during drought
Status Quo	0	0	0	0	0
Increase Summer Pool by 17 feet	0	+	+	0	+
Reduce target flows	0	+++	--	0	0
Override rule to conserve water in Summersville	0	-	+	0	0
Delay start of WQ releases	+	++	++	0	0
Vary the amount of WQ releases	+	++	+	0	0

KEY: - means an adverse impact; + a positive impact; the more +’s or -’s, the greater the effect of the plan

Once the agreement is signed, the greatest threat to its effectiveness will be the passage of time and the press of other concerns. As time passes, the threat of drought will seem more distant, the staff members and stakeholders will work on other projects, change careers, or retire. The next chapter describes how to exercise and update the plan.

FIGURE 13. A SAMPLE PARTNERING AGREEMENT.

This agreement expresses our recognition of common goals and shared responsibilities in the management of water in the __________ basin during drought. This agreement builds upon the mutually beneficial relationships which already exists among the stakeholders and agencies involved in the management of the _________ system.

A shared vision model of the _______ system was developed during the recent _______ DPS to help resolve conflicts and reach consensus among resource managers as mutually acceptable operating plans are developed during periods of water shortage.

In recognition of the threat water shortages present to us all, and to provide a foundation for management of the shared vision model, we agree to:

- Work together as regional partners, in an atmosphere of cooperation, open communication and trust, to encourage a problem-solving attitude.

- Use the shared vision model to enhance and improve resource management in the _________ system. The model will be available for use by all parties involved in making water resource management decisions, to facilitate independent evaluation and development of alternative operating scenarios. _____________ will maintain the official version of the model.

- Participate in virtual drought exercises in the spring of even numbered years. The purpose of the VDE is to exercise and update our collective drought response.

- Convene a meeting of the signatory groups whenever any of us requests to determine whether to implement a drought response.

To ensure that the official version of the model contains current and accurate information, streamflow data will be updated as needed by _____________. Changes which affect model operation and/or outputs (i.e. addition of system components or correction of errors) will be documented and reported to all of us for consideration.

Resource managers are encouraged to modify the model, to aid them in identifying and evaluating management strategies and to develop new insights. They are also encouraged to inform others of such modifications and their effects on model operation.

___________ will maintain a list of agencies involved in the management process that have been given access to the model. This list will be distributed to all signatories.

Designated points of contact for each signatory agency will meet regularly, in conjunction with scheduled interagency coordination meetings, to review the model, its use, and changes to the model.

9 EXERCISE, UPDATE, AND USE THE PLAN

A drought plan, like a fire evacuation plan, will be most effective if exercised regularly. Like a fire drill, a drought exercise can show new people and remind veterans what the plan is. But unlike a fire drill, water managers are apt to find the corridors have changed; water uses diversify and intensify in the years between droughts, and new stakeholders must be brought into the process. When droughts do occur, the plan will be tested, and managers will have a unique and valuable opportunity to learn if they consciously record the events during the drought and compare them to their expectations.

Some of the good work done in the preceding steps can be undone by the passage of time. It may be several years after a DPS before another drought occurs. During that time, professional staff may change jobs, water uses may change in nature and quantity, and new laws may be passed that affect the way the water system can be operated. The result is that the trust and familiarity developed during the DPS will diminish, and the region's vulnerability to drought will gradually return.

The solution is to exercise the plan. It is a simple concept, used quite commonly in other areas of hazards management from fire drills to military maneuvers. The idea of a *drought exercise* has been used since the early 1980's by the Interstate Commission on the Potomac River Basin (ICPRB), which coordinates water management in the Washington Metropolitan Area (WMA). An annual exercise is important for the Potomac because coordinated management of several water systems was used in lieu of additional storage to increase the safe yield of the collective system.

VIRTUAL DROUGHT EXERCISE

During the conduct of the four demonstration studies, Dr. Richard Palmer, a University of Washington researcher and the developer of the simulation model used in the first Potomac exercise, suggested that the shared vision models and close collaboration among stakeholders in a DPS would make it possible to simulate a drought more realistically than ever before. The resultant ***Virtual Drought Exercise*** could be used in the years after a tactical drought plan had been designed to exercise a regional drought preparedness strategy. This would let agencies address new water uses and train new staff and stakeholders. The first virtual drought was held in Tacoma, Washington on August 4, 1993 as part of the Cedar and Green River Basins DPS. It was well received by the participants and can be used as a model for other regions interested in exercising water plans.

A Virtual Drought Exercise should have the following elements:

- a facilitator, to explain the rules of the VDE and manage the time spent on negotiations;

- participants, namely the people who would represent water agencies and stakeholder groups during a drought;

- a member of the press or a public affairs person to represent the needs and influence of the media;

- data synthesized for the exercise, including forecasts, initial storage amounts, inflows, and demand variables. Virtual droughts should require participants to confront the uncertainties of real droughts concerning future precipitation, streamflow, and consumer responses to drought measures. Although the designers of the VDE will know all the hydrologic data for the exercise, they should not share them with the participants except as they are revealed during the unfolding of the virtual events.

- two versions of the shared vision model, modified for this specific application. The first is used by the facilitator to track the performance of the system as decisions are made. The second is used by the participants to estimate the impacts from alternative management decisions;

- a scoring system (optional) to measure the performance of the participants.

The Tacoma virtual drought took place during one seven-hour session in a large conference area. Each segment began when the facilitator ran his version of the shared vision model to simulate from 2 to 6 weeks of system operation. The facilitator then announced the new system states (reservoir levels, release patterns, shortfalls, etc.) and called for a "forecast". After the participants questioned the forecaster, they used a second version of the shared vision model to estimate drought impacts under different policies. The sensitivity of the impacts to forecast errors was also analyzed by using a range of forecasts centered around the published forecast. Participants then negotiated decisions as they would during a drought on such issues as minimum flow requirements, the imposition of water curtailment measures, the supplementation of surface supplies with groundwater, and changes in reservoir operating policies.

Debriefing discussions were held immediately following the exercise. The universally high level of attention and occasional signs of irritation brought out during the exercise offered testimony to the realism of the exercise.

USING THE PLAN

The difficulties of using the recommended plan during a drought should be greatly reduced by regular exercise. In only one case (the Kanawha River) has a drought threat occurred since a DPS plan was adopted. The use of the shared vision model and the coordination mechanisms developed during the DPS would have avoided millions of dollars in losses to regional tourism had the 1993 drought continued. The DPS team in the Kanawha was pleased that the DPS process worked so well, but the real test will be whether the advances from the DPS will be as effective in ten years.

There could still be a problem recognizing that a drought has begun. Although the

DPS plan should have well defined triggers for each phase of a drought response, using them still requires human monitoring and judgement.

When droughts do occur, it is important to discuss and record what was learned about the weaknesses of the planned response. Drought preparedness can be improved through both drought simulation and experience. The first has the advantage of allowing the consideration of a broad range of droughts, but the disadvantage that it will never have the urgency of a real drought.

A drought focuses public and political attention in a way no exercise could, and reveals physical, environmental, and economic interconnections that planners might have been unable to imagine. The primary drawbacks of experiential learning are that it requires loss or failure, and it is based on one specific event. Agencies may be reluctant to document their learning because to do so might seem to them the admission of error. Alternatives unacceptable before a drought may now be implementable.

Water resources experts have advocated multidisciplinary, multiobjective, multipurpose water resources planning on a watershed basis for decades. The DPS method is built on the principles of water resources planning developed by leading universities and tested by federal agencies since 1936. The DPS method updates and modifies those principles to make them more suitable for regional and tactical studies. The usefulness of the method should be expanded as experience in non-drought water management cases increases, and new developments in software make it possible to fulfill the promise of "shared vision models" at an even higher plane.

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10 CONCLUSION

There are at least twenty-five separate water programs, governed by more than two hundred federal rules, regulations and laws.

Peter Rogers (America's Water, 1993)

Traditional responses to water supply problems, such as construction of major water projects, are limited today by economic, environmental, and social concerns ... there is a shift in emphasis to improved operations and management of the existing facilities and systems and transfers of rights to new, more efficient uses.

Western Governors Association, Report on the May 16-18, 1991 Park City Workshop

(Natural resources policy making is) "... a fluid, anarchic world of professionals, unmoored from the voters, seeking ideas that will solve problems, many of which lack clear outlines ..."

Kai Lee (Compass and Gyroscope, 1993)

To produce more from our existing water infrastructure, we must pursue more sophisticated policies and operational procedures, coordinated among many agencies. The cleverness that secures these gains will probably mean that water management policies will be more difficult for the average citizen to understand.

The DPS method can help. It adds the illustrative and analytical power of the shared vision model to water resources principles solidly established in theory and practice. But a good method does not obviate the need for excellent water managers; the DPS method cannot work without them.

A truly interdisciplinary team is necessary; that means not only a team well schooled in the many requisite fields of learning, but one in which each professional recognizes that the perspectives and analytic tools of other professions can improve the chances that the team will be successful.

To overcome the fractiousness of multiple agencies and stakeholders, individual team members must be results oriented. That means that staff professionals must accept a personal responsibility for regional progress while fulfilling their obligation to pursue agency missions. And it means that stakeholders and advocates must compare possible but imperfect solutions to the *status quo* - the no improvement alternative.

In the near term, this means that DPS team members must be carefully selected to obtain this mix of leadership, scholarship, and integrity. In the longer term, it means that schools and agencies must work together to make sure that people of this caliber will apply themselves to these problems.

DPS PLANNING PROCESS CHECKLIST

The seven steps of the DPS process are conducted iteratively; that is, the team will go through the sequence of steps more than once, decreasing the breadth but increasing the depth of their analysis in each iteration. The checklist below portrays the DPS study process as it might occur over time. The sequence of events will vary from study to study because some tasks (such as new environmental and economic studies) may not be instituted until a need for them is demonstrated. Evidence for that may come in the initial workshop of one DPS, but may not come until the preliminary analysis of alternatives is done in another DPS.

Clearly, steps one and two dominate the early part of the study, and the seventh step occurs at the end and after the study is complete. But team members will discuss alternatives from the first day, and redefine decision criteria and planning objectives as they learn more about the status quo and the nature of alternatives. Steps 4 and 5 are by nature the most iterative. The generation of a very long list of alternatives is important because it helps assure that no options have been overlooked and helps broaden "ownership" of the process because it allows all DPS members to submit their ideas for consideration. But before any alternative is developed in more detail, the DPS team should apply screening criteria to all alternatives. Screening is the first iteration of Step 5, evaluation of alternatives. Screening will eliminate the ideas that do not address the planning objectives, or that have been shown to be ineffective. It will also identify alternatives that are incomplete and need further development to be evaluated at any level. The alternatives that pass through the screen can be formulated (second iteration of Step 4) in more detail.

A DPS begins with a precipitating event that establishes the need and provides the resources to conduct a DPS. The initiative can begin with a political mandate, leadership within a management agency, or inquiries from stakeholders or advocacy groups

The convening agency makes a preliminary identification of decision makers, stakeholders, advocacy groups, and independent experts and writes letters inviting them to attend an initial problem identification workshop. In the letter, the agency asks for a commitment from decision makers to empower the DPS process

An initial workshop is held. The purposes of the workshop are to:

- define the range and severity of drought problems facing the region

- list additional decision makers, stakeholders, advocacy groups and independent experts that should be involved in the DPS (the list can be compiled by filling in Table II, page 22).

- identify the conditions necessary to secure the necessary commitment from decision makers to empower the DPS process

- establish that drought impacts constitute a significant regional problem and that it is the actions of the workshop participants that will reduce drought impacts in future droughts (if the facts do not support that finding, then the DPS may not be required)

- identify additional sources for information, both in the form of written reports and personal expertise

- develop an initial organization of workshop participants into circles of influence

- define the geographic limits and time horizons (planning period) of the study

- determine if there are other strategic or emergency water management efforts

Review existing reports on regional droughts and the subject of water management for drought (agency reports, news stories, university research papers, journal articles, publications and proceedings of organizations such as the American Water Resources Association (AWRA), American Water Works Association (AWWA), American Society of Civil Engineers (ASCE).

At the first or second workshop, the DPS team would:

Determine the broad goals for managing water during drought (such as economic efficiency, equity, environmental protection) and make a preliminary determination of the criteria decision makers will use to determine whether the recommended plan from the DPS team meets these broad goals

Develop specific planning objectives and constraints (if any) related to each of the applicable water management purposes

Identify the performance measures that managers and stakeholders use to judge the adequacy of water management systems

List the types of *effects* of water management decisions, how they are related to decision criteria, and how they could be measured

At this point, in more intensive DPS's, the team may initiate an issues study. The purpose of the study is to document the political issues that underlie the criteria that decision makers will use to accept, reject or modify the DPS team's recommendations.

develop a shared vision model of the status quo based on existing reports, specialized water resources models, and interviews with DPS team members. The model should diagram and quantify the relationships between stakeholders' and advocacy groups' concerns and the availability of water at a specific place and time. It should also diagram and quantify the relationship between the availability of water and water management decisions under the current set of institutions and infrastructure. The status quo includes the current set of water management institutions and infrastructure and probable future changes initiated outside the DPS (for example, the effects of national plumbing codes on municipal water use, or the effects on water supply from future infrastructure investments justified and implemented outside the DPS).

consult the National Drought Atlas and other sources to gauge how likely it is that the drought of record will be eclipsed by larger droughts within the planning horizon consult the Atlas and other sources to determine how likely it is that future droughts will have a different geographic focus or starting month, or longer duration.

select the appropriate design drought(s) to test the adequacy of existing and proposed drought plans

model the performance measures, constraints, objectives identified in step 2.

In more intensive DPS's, the team may commission new surface and ground water modelling studies that use specialized computer models distinct from the shared vision model. The team may also commission demand element studies to determine potential future use of water for each water management purpose. If the team expects that some alternatives may hurt some stakeholders and help others, environmental and economic studies should be instituted now. The studies can determine the change in the magnitude and distribution of economic and environmental effects associated with changes (from the amounts provided under the status quo) in the quantity of water delivered for each water management purpose.

commission hydrologic studies to develop more elaborate synthetic inflow data sets, or "natural flow" data sets

At a workshop, or through another group process such as the *Delphi process* (page 16):

generate an exhaustive (uncensored and uncriticized) list of alternatives

screen the alternatives to determine if they are complete and meet minimum standards of effectiveness and acceptability

determine whether the alternatives are strategic, tactical and emergency responses

develop one or more tactical drought response plans, combining elements of the tactical alternatives suggested. Tactical plans may differ from one another in degree or type. For example, two plans may differ only in the trigger levels at which water use curtailment is imposed. But other alternatives might be radically different, such as the imposition of temporary price increases or water banks *in lieu* of curtailment plans. Early draft plans can be evaluated and reformulated though workshops or the Delphi process.

develop a shared vision model of each alternative plan that will be seriously considered.

run the model(s) to measure the performance and effects of the alternatives under the conditions of the design drought(s).

compare the effectiveness, acceptability, performance and effects of all the alternatives. Publish these results for review.

hold a workshop to select the plan the DPS team will recommend. This may require more than one meeting. If there is an alternative that requires little or no expense, hurts no stakeholder but helps some stakeholders, recommending a plan may be relatively easy. If that is not the case, then the DPS team must compare the effects of each alternative within each account. If an alternative takes something from a stakeholder but is more economically efficient and environmentally sound, then the DPS team may decide to recommend the alternative, after modifying it to mitigate the loss or compensate the losing stakeholder to assure the goal of equity is met. If an alternative is most economically efficient but has adverse environmental impacts (or vice versa), then an additional round of reformulation and negotiation will be required, or the DPS team may elect to accept the status quo. The team may elect to do an *incremental cost analysis* of environmental mitigation measures to develop a more acceptable tradeoff between environmental and economic effects than either the status quo or the previous alternatives produce.

write a report that clearly explains the recommendations of the DPS team. The report should display the findings according to the steps in the process: *problems and team members; criteria and metrics; the status quo; alternatives; and the evaluation process*.

identify the actions that will be required to institute the recommended plan, including environmental assessments, and the ratification necessary to institutionalize tactical and emergency plans.

develop a clear, powerful presentation of the study team findings and present as a team to the decision makers who must approve the recommendations of the DPS team.

given the approval of decision makers, develop partnering agreements and new regulations. It would be unusual for strategic changes to be implemented as a direct result of a DPS, but the team can identify the processes (such as legislative action) that would be required to institute strategic changes.

negotiate and institutionalize an agreement to exercise and update the new plan on a regular basis

After the end of the study, the DPS team will:

use an updated version of the shared vision model to conduct Virtual Drought Exercises

implement the plan when droughts occur and document and record the lessons learned from the application of these measures in a real drought.

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A - ORIGINS OF FEDERAL WATER RESOURCES PLANNING GUIDANCE is a very brief overview of the decades of debate, research, and practical experience with Federal water policy that produced comprehensive, usable guidance about how to meet conflicting water management goals.

B - POLITICS, ADVOCACY GROUPS, AND WATER AGENCIES describes the difficulties water agencies have in melding their analysis with the perspectives of elected officials and advocacy groups, and offers practical advice for doing better.

C - COMPUTER MODELS OF WATER AND RELATED SYSTEMS raises and responds to key issues in developing shared vision models.

D - WATER LAW AND DROUGHT lists eight significant water law issues, and the ways different states are dealing with them.

E - ENVIRONMENTAL EVALUATIONS: KEY ISSUES FROM THE CASE STUDIES and F - ECONOMIC EVALUATIONS: KEY ISSUES FROM THE CASE STUDIES are not treatises on economics or environmental sciences; these annexes address some practical questions that were raised most frequently in the National Drought Study case studies about how these fields fit into drought management.

G - HYDROLOGY explains basic concepts in drought hydrology

H - ALTERNATIVE DISPUTE RESOLUTION is a primer on the subject, with a description of how a shared vision model can help an ADR process.

I - DROUGHT AND THE PUBLIC includes a brief history of public involvement in water resources and some practical lessons learned.

J - CONCEPTUAL BASIS FOR CIRCLES OF INFLUENCE describes the theory and practice that inspired this simple but effective idea.

K - FORECASTING WATER USE TO MANAGE WATER CONSERVATION explains what disaggregated water use forecasting is and how it can be used to make sure conservation programs are more cost effective.

L - LESSONS LEARNED FROM THE CALIFORNIA DROUGHT 1987-1992 is a 7 page summary of longer reports (NDS-5 and 6), with some additional new information.

M - THE PRINCIPAL NATIONAL DROUGHT STUDY CASE STUDIES includes thumbnail sketches of each case study.

N - THE NATIONAL DROUGHT ATLAS depicts the type of data in the Atlas and shows one way it can be used.

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A - ORIGINS OF FEDERAL WATER RESOURCES PLANNING GUIDANCE

The DPS method is a hybrid. Although based on planning tools that have been used primarily to evaluate the feasibility of federal water projects, the DPS method was used to evaluate the advisability of one short term operational plan over another, usually with a fairly modest federal interest. This annex will explain why the federal guidelines were so influential and will state how the DPS method differs from and co-exists with the latest federal planning principles.

In the first year of the National Study of Water Management During Drought, several experienced water planners were asked to review the literature on water resources planning and propose specific drought planning approaches. In addition, published and unpublished preparedness methods developed specifically for drought were reviewed. There were two basic critical questions used in evaluating these approaches:

- *Was the approach internally consistent and complete?*

- *Would the method reduce the negative effects from drought?*

The negative impacts of drought were the subject of television news almost nightly in 1988. The impacts cut across all the purposes of water management. Many could be expressed in economic terms, but others were purely environmental or social. Investigations conducted by the National Drought Study team and others showed that most drought plans had not been designed to reduce the effects of drought; most were intended to ration shortages without regard to the impact proportionate reductions would have on different water users.

This contradicted the premise of multiobjective water resources management, which is that water should be managed to produce the best balance of the intended objectives. Multiobjective evaluation procedures had been integrated into the principles which guided federal water resources feasibility studies. In fact, scholars and water managers had tested and applied several generations of water resources planning methods; no other planning approaches had anywhere near the amount of testing and thought invested.

The current federal method (Principles and Guidance), however, had a very narrow plan selection process; P&G call for the selection of the plan that reasonably maximizes National Economic Benefits (NED). Since there might or might not be a significant federal interest in regional droughts, it was clear that this would be an inappropriate condition for plan selection. But, absent the simple NED objective, what decision making rules should be embedded in the DPS planning method?

The advantage of the federal planning principles. The very brief history of federal water resources planning that follows is meant to introduce readers unfamiliar with that history to the investment, testing, and high level criticism that have shaped and refined the federal water resources planning and evaluation procedures. Accordingly, developments related to these aspects are emphasized in what follows. Other matters, (which were of great national interest and concern at one time), such as proposed realignment of water resources responsibilities in government and/or creation of additional valley authorities, are omitted because they are irrelevant to the purposes of this report.

The requirement to perform a benefit-cost analysis in a federal water resource project study originated in the 1936 Flood Control Act. The federal government was authorized to participate in the construction of flood control projects if "the benefits to whomsoever they may accrue are in excess of the estimated cost." This was a clear expression of the federal interest. This requirement of "economic justification" was subsequently extended to other water resource project purposes. Interpretation of the economic justification requirement resulted in the development and evolution of various analytical procedures and the promulgation of a number of policy statements, both formal and informal.

During the New Deal era, executive branch policies favored the use of secondary and intangible benefits to evaluate projects. These benefits were believed to embody the social reasons why water resource projects were wanted. As the recession, and later the war came to an end, the Bureau of the Budget no longer accepted the use of these benefits. By the early 1950's, economic justification procedures relied almost entirely on "national economic efficiency," i.e., a favorable benefit-cost ratio using benefits as identified from the national economy's perspective.

There was soon a perceived need for coordinating activity between the federal agencies and the states. This was done initially by river basin committees, created by interstate compact. These were the forerunners of the later river basin commissions. However, new ideas now began to arise. This was an era of rapid, large-scale water resources development. Interest in water resources rose both in government and in academic circles. There was competition among federal water agencies, and significant discrepancies in such matters as the methods of estimating benefits and allocating costs among project functions. There was also a perceived need for greater coordination between agencies in the planning of water resources development in large river basins.

In May 1950, the Interagency Committee on Water Resources issued a report known as "The Green Book," which, although not mandatory, was influential among the agencies concerned in establishing sounder policies on controversial matters such as benefit estimation, discount rates, and allocation of costs. It also stated in general terms that "For federal projects, a comprehensive public viewpoint should be taken."

In the late 1950's, the Harvard Water Program developed a body of thinkers who considered the basic economic approach to water resources project feasibility to be too narrow, and favored multiobjective project evaluation. This method required trade-offs between all classes of benefits. This intellectual stimulus had far-reaching effects. President Kennedy, after only seven months in office, sent proposed legislation to Congress creating the Water Resources Council, with extensive powers. An *ad hoc* Water Resources Council in 1962 helped develop Senate Document 97, which revised standards for benefit-cost analysis in ways expected to justify more projects.

In the field of flood control, the simple paradigm of continually building more flood protection as flood damages increased was replaced nationally by the concept of providing flood plain management to minimize flood damages, and of resorting to flood control construction only when necessary. The North Atlantic Regional study of the Corps provided a testing ground for multiobjective planning.

And finally, a long-standing controversy on proposed water supply improvements on the Potomac River had showed that operational coordination between various systems concerned could make very large improvements in safe yield, obviating the need in this case for a whole series of additional reservoirs.

On the national political level, the great environmental movement starting in the sixties led to passage of the National Environmental Policy Act of 1969, and the Federal Water Pollution Control Act of 1972 (now known as the Clean Water Act). Under the Clean Water Act, the programs of EPA were made completely independent of the planning criteria of the Water Resources Council and of the general idea of balancing benefits against costs.

For water agencies other than EPA, in 1973, the now formally constituted Water Resources Council issued "Principles and Standards for Planning Water and Related Land Resources" (P&S). The principal new feature of this document was to require that project plans be prepared separately to emphasize national economic development and to enhance the quality of the environment. Other objectives to be recognized were regional development and social well-being, but specific plans for those purposes were not required. Both positive and negative effects upon each purpose were to be displayed.

There was no clear concept as to how to reconcile divergences between environmental and economic goals. The main policy was that they should be explicitly recognized, compared, and considered in project formulation. Specifically, for reasons of environmental quality, agencies could select a plan other than the one that maximized national economic benefit. This P&S represented the further extension of the ideas of the Harvard Water Program. The P&S required a six step iterative planning process, as follows: (1) Specify problems and opportunities; (2) inventory and assess water and related land conditions; (3) formulate alternative plans; (4) evaluate effects of each alternative; (5) compare the alternatives based on effects; and (6) make recommendations. Of course, this general process corresponds closely to the recommended approach for DPS as described in Chapter 2 of this report.

Beginning in the late 1970's, federal water resource development programs came under criticism, especially within the Reagan administration. In 1983, the P&S was replaced by "Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies" (P&G). The P&G apply in all Corps of Engineers, Bureau of Reclamation, Soil Conservation Service, and Tennessee Valley Authority implementation studies for civil works water project plans.

Most of the principles of the P&S were carried over into the P&G, except that, under the P&G, National Economic Development (NED) benefits are more important in plan selection than in the P&S. Under the P&G, planners are not required to develop an Environmental Quality plan. The recommended plan is (unless an exception is granted by the Assistant Secretary of the Army for Civil Works) the one that *reasonably* maximizes net NED benefits (consistent with protecting the nation's environment). The selection of projects which maximize NED is subject to environmental laws and constraints in a process best described as constrained optimization.

The four accounts into which project effects are to be classified are:

- National Economic Development (NED)

- Environmental Quality (EQ)
- Regional Economic Development (RED)
- Other Social Effects (OSE)

The P&G and its four accounts system of displaying information provide a comprehensive, consistent, and systematic methodology for evaluating plan impacts. Its basic theory is very similar to that of the P&S. In either case, the undoubtedly sound principles do not avoid the inherent difficulties of quantifying many of the non-economic values encountered in water resources planning, particularly in drought planning.

There is a conceptual problem related to DPS which remains unresolved. The Corps of Engineers, and most other water agencies, use the maximization of NED as the objective when planning a new or revised federal project. This is mandatory. However, the states and municipalities, which between them will be required to pay for water supply costs (including federal construction costs), are justifiably concerned with regional economic development (RED), as explained in the main report and Annex F. For impacts on which evaluation of NED and RED differ markedly, this difference may have to be recognized and covered in negotiation, since the P&G procedures cannot be held to be automatically applicable to planning by states and their subdivisions. With respect to federal participation, the principles of the P&G are fully applicable in the DPS, although the cooperative procedures used are somewhat different from those used in project planning by the Corps.

Besides the issuance of the P&G, two other developments have considerably changed the conduct of water resources planning. First, the Reagan administration eliminated funding for the Water Resources Council and inactivated most of the River Basin Commissions. This change increased the difficulties of assuring effective interagency cooperation. Secondly, the passage of the Water Resources Development Act in 1986 increased the cost-sharing requirements of most non-federal partners, including non-federal contributions to feasibility studies. Non-federal interests are now required to assume the full cost of water supply improvements, even though they take the form of construction or reconstruction of federal reservoirs. Although it may be argued that the regional effects of a major drought are analogous to those of a major flood, the federal government has not assumed the same responsibility for drought control that it has for flood control. Therefore, federal planning for DPS must be undertaken without any substantial federal financial contribution to remedial projects.

B - POLITICS, ADVOCACY GROUPS, AND WATER AGENCIES

There are characteristic differences in the way elected officials, advocacy groups (such as environmental or growth management groups), and water agency staffs engage in the conduct of water management. The way these dissimilar patterns mesh can itself influence the effectiveness of water management and drought preparedness. Two hypothetical examples help illustrate this:

> *Agencies and elected officials.* A regulatory agency might refuse to grant a permit for a new city reservoir, arguing that the same level of water service reliability can be achieved at less cost through water conservation. But the mayor of the city might support the reservoir, because it would also provide the city bargaining power in negotiations to secure regional cooperation on wastewater, transportation and police protection. In this case, the difference in approach is in conceptualization; because of their more narrowly focused role, some water resources agencies may not consider the mayor's decision criteria. Is there a solution which can address the concerns of both the agency and the mayor? If there is, it is unlikely to be identified unless a conscious effort is made to bridge the two ways of seeing the problem.
>
> *Agencies and advocacy groups.* Environmental groups gained their initial leverage in water resources through legislative lobbying and the courts to stop water projects, not through collaborative planning for water supply solutions and the operation of existing projects. But, getting new laws and court rulings can take a long time and a lot of money, and the results may not please any stakeholders. A similar risk applies in legislative action, which requires majorities to be assembled through negotiation among members on many collateral issues. This might include budgets, taxes, crime prevention, education, air pollution, growth, traffic management, fire fighting, trash collection, waste management, health care, and relations with other governments.

The importance of *intergovernmental* and *interagency* "meshing" has been recognized by the creation of commissions to manage those relationships. However, the choreography of elected officials, environmentalists and water agency staffs in water management is often left to chance. Successful interactions are celebrated because of their rarity. Anecdotal evidence indicates that successful interaction is a function of the personalities involved.

This annex highlights some types of situations that were most often described as problematic by water managers, elected officials and political appointees, and environmentalists during the National Drought Study. The discussion of typical situations is followed by suggestions for addressing those situations developed with the U.S. Advisory Commission on Intergovernmental Relations (ACIR) and other social science experts.

Agencies and elected officials.

Situation 1. Citizens turn to elected officials for help during drought, but the officials have not been involved in agency planning efforts.

Political involvement in water management is most intense during the authorization of capital intensive water projects or the imposition of regulatory statutes. Years may pass between the signing of a bill and the next severe drought. During that time, water uses may become more diverse and intense. Drought plans, if any are developed, may be done agency by agency. Too often, it requires the onset of a drought for these issues to be raised to a political level, and as a consequence, elected officials learn of the insufficiencies just after their constituents ask them to make the system address their needs. Elected officials cannot defend a non-responsive system, but their criticism, often seen as scapegoating by agency staff, may hurt agency morale. Moreover, water management decisions developed and implemented at a primarily political level during a drought may not serve the best long term interests of the region.

Situation 2. Elected officials have not communicated broad water management goals to agency staff. This is the least true at the federal level. The Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies (the P&G) spell out what the President and Congress want federal agencies to consider in evaluating water projects. These are general principles and guidelines; planning objectives are developed for each study. But few cities and counties have developed analogous guidelines. How then, can a regional drought preparedness team determine the criteria that several mayors, state senators, city council members, and the governor will use in determining whether to support and implement a drought plan? The traditional method is to rely on the political acumen and articulateness of the agency staffer reporting to each elected official, but those skills vary from staffer to staffer, as does their access to political leaders.

Situation 3. Agencies have not kept elected officials advised of new drought vulnerability. This occurs not because an agency fails to fulfill its mission, but because agency missions encompass pieces of water management, and the vulnerability is often apparent only when a water system is viewed holistically. Division of responsibility typically reflects one or more of three fundamental conceptual divides: surface water and groundwater, water quantity and quality, and the water management purposes (such as irrigation and navigation).

Droughts reintegrate these conceptual distinctions. A shortage of surface water could be addressed by pumping groundwater; low flows reduce the capacity to dilute effluents; irrigators and navigators must find a way to share scarce water. Where and how is the problem managed holistically? Organizational charts show where integration of the missions of individual agencies occurs. It is generally at a political level, such as the President's Cabinet or a legislative water commission. But the small staffs at this level are often too far removed from field data or too engaged in the pressure of other issues to analyze trends for potential problems.

Solutions

As with most studies, the agency staff engaged in the DPS's were asked to keep their political bosses informed of the team's efforts, and letters were sent to officials at critical junctures in the studies by the study leaders. Two measures were used to address the three typical situations described above, and the DPS teams felt that they improved the effectiveness of the relationship between agencies and elected officials:

1. Political scientists were asked to conduct surveys to determine what elected officials expected from drought preparedness efforts. The U.S. Advisory Commission on Intergovernmental Relations (ACIR) conducted two such studies. In Virginia, Vivian Watts (a

former Virginia state legislator and Secretary of Transportation) met with the Virginia legislature and Virginia water experts and wrote a report that explained the position of each side on the issue of the development of a state water policy. Her study increased the understanding each side had of the other's position, and helped support movement within the Virginia water community to revisit the issue of a state water policy. The Virginia Water Commission, a group of state legislators, met on July 21, 1993 to consider ideas - including those of the James River DPS team - for a more proactive state water role. Testimony was offered by National Drought Study representatives, and the shared vision model was demonstrated.

In the Seattle area, David Harrison, Helen Birss, and Dean Ruiz of the University of Washington's Northwest Policy Center interviewed the mayor of Seattle and Seattle Council Members, as well as water agency staff in an effort to describe political and water agency perspectives on regional water management. Other DPS team members were pleased with these study reports because they:

described the regional political context more fully than any individual agency staffer understood it;

represented the views of each elected official evenly, avoiding the problem of political interpretations by misinformed, biased, inarticulate, or unempowered agency staffers;

brought the DPS to the attention of the officials. The interviews provided an opportunity for a limited, but informal briefing on the study in progress. (The political scientists had been thoroughly briefed on the study before conducting the interviews.)

There were still concerns about whether elected officials had spoken openly about hot regional issues, but the information from these political studies was used to supplement information the DPS team received from more general sources such as the local press and agency briefings.

2. In the Green River DPS, a "demonstration" workshop was held at the close of the study, after technical experts had engaged in a Virtual Drought. The demonstration workshop, shorter and less technical than previous DPS workshops, was meant to show the broad implications of the DPS agreements to staff directly engaged with mayors and governors. Whereas the technical workshops had focused on hydrology and technical models, the demonstration workshop addressed issues of public relations and regional cooperation and showed how technical staff had been able to create a working, regional partnership.

Agencies and Advocacy Groups

Situation 4. Advocacy groups and agencies are not used to working together. Prior to the National Environmental Policy Act (NEPA) of 1969, water agencies had much less legal obligation to disclose environmental impacts to the public, including environmental groups.

Despite the considerable investment of time, dollars, and personnel that participation efforts received during the 1970's and 1980's, many conflicts over resource management issues continued to land in court. Collaborative planning efforts between environmental groups and agencies are still unusual. In some cases, environmental groups may consider it in the best interests of the world and their organization to avoid collaboration, fearing that financial and personal relationships could diminish their role as critics.

Solution

While legislative and judicial intervention may have been the best use of limited advocacy resources in the dam building era, some environmental groups are changing their method of operation. For example, Edward Osann and David Conrad, then with the National Wildlife Federation, developed the conservation plans for the latest increment of the Central Utah Project, a Bureau of Reclamation project first authorized in 1956 (Monberg, May 14, 1992) DPS teams should recognize three things:

1. Planning collaboratively with environmental groups is the only way to fully consider their points of view. Alternative points of view raised late in a study must not only prove themselves, but overcome the momentum that established ideas have developed within the team. Moreover, time and funding constraints discriminate against the consideration of last minute ideas.

2. Planning collaboratively with environmental groups is a good way to assure that environmentalists understand non-environmental planning objectives and share the responsibility for addressing those objectives.

3. Environmentalists generally offer a broader perspective on river basin management issues because they have not had to pursue agency objectives, which are usually fairly narrow. Because of this, they may help a DPS team think holistically and become results oriented, rather than process oriented.

4. Environmental groups are not all the same. Some have deliberately chosen to become collaborative, some to stay within the role of critic, and some, like the Nature Conservancy, which buys land and sets it aside for environmental purposes, to find solutions that require neither collaboration or confrontation. Unless there is an ongoing or imminent adjudicative relationship, DPS teams should reach out to environmental groups that can help *or* block a study and negotiate a suitable level of involvement.

The DPS method names advocacy groups as one of the four types of participants that should be involved in any drought study. The "Circles of Influence" method of managing study participation permits advocacy groups to become as involved as their resources allow; the main requirement for membership in the inner Circle A is the ability and willingness to work on the study.

Situation 5. Collaborative planning is impeded because an advocacy group could be a potential adversary in court. This applies to adversaries who are *not* advocacy groups, as well. The DPS and other collaborative planning processes are rational methods; the "best" decision requires trust and a full sharing of information and objectives, including uncertainties about data and relationships. The judicial process is adversarial; a champion for each adversary presents one side as vigorously as possible and diminishes opposing views through whatever legal means that champion can muster. The "best" decision is made by a third party who has heard all sides and been informed of past case law. Information sharing in a judicial process is called "discovery" and involves court ordered access to an adversary's files. Thus, pursuing a DPS can diminish the chance of success in an adversarial process, and vice versa. Alternatives that stakeholders choosing between collaboration and lawsuits should consider include:

1. **Do both.** In some cases, stakeholders have pursued both approaches at once. During the recent drought on the Missouri River, Corps of Engineers and the Missouri

River basin states collaborated in a review of the operation policies of the Corps Main Stem Missouri River reservoirs, while at the same time North Dakota, South Dakota and Montana brought suit on related issues in federal court in Billings, Montana. No study has been done to estimate the effect one approach has on the other.

2. **Formally discontinue the suit.** Alabama and Florida agreed to stop pursuing a judicial solution and signed a memorandum with Georgia and the Corps of Engineers to conduct the Alabama-Coosa-Tallapoosa and Apalachicola-Chattahoochee-Flint River Basins Comprehensive Study. If the participants in an active or imminent water suit believe that a collaborative process would increase the probability of a mutually desirable outcome at a lower transactional cost, then they might consider a formal process, developed with the help of alternative dispute resolution experts, that defines the conditions of a cooperative joint study. The study process can then proceed deliberately until one or the other partner feels that judicial proceedings are unavoidable.

3. **Create a new relationship**. The **Water Supply Citizens Advisory Committee** in Massachusetts is a model for how adversarial relationships can become more productive without a loss in the diversity of values represented in water management decisions. In brief, a group of environmentalists, citizen activists and academicians sought to block the plans of the Metropolitan District Commission (MDC) (supported by the Corps of Engineers in its Northeastern United States Water Supply Study) to divert water from the Connecticut River to supply Boston. They argued that it was unfair for Boston to create transbasin diversions before managing its water demands. The opponents metamorphosed through several organizations from 1969 (Connecticut River Information Clearinghouse) to the Water Supply Citizens Advisory Committee (WSCAC) in 1980. WSCAC played an important role in the creation of the Massachusetts Water Resources Authority (MWRA) in 1984, which took over the responsibility for delivery and distribution of water for 46 communities from the MDC.

Of greatest interest to other communities is the current relationship between MWRA and WSCAC. MWRA provides funding for office space, expenses and staff for WSCAC. The staff is answerable only to WSCAC, not MWRA. WSCAC directors can access MWRA computer files using a WSCAC computer. MWRA consults with WSCAC while developing management strategies, so that published strategies have already received the benefit of an environmental perspective. WSCAC has its own network of advocates and experts, so a pattern of communication and trust similar to the Circles of Influence has been established.

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C - COMPUTER MODELS OF WATER AND RELATED SYSTEMS

The most visible innovation of the National Drought Study is the way computers were used in developing strategic and tactical plans. This innovation continues the long tradition of computer usage within the Corps of Engineers that began in the early 1950's. Conversations between William Whipple, who was then executive officer to the Assistant Chief of Engineers, and John von Neumann, a mathematician at Princeton's Institute for Advanced Study, resulted in the Corps using computers to calculate river stages and reservoir operating plans. Computers have since been applied by the Corps to all aspects of their multi-disciplinary analysis, including hydraulics, hydrology, economics, ecology, law, and decision making.

The contribution of the National Drought Study to this tradition is the use of new software to bridge the gap between specialized water models and the decision making process used by people. The computer software used in these efforts can be described as a user-friendly, graphical simulation tool. This software makes use of icons to represent simple, physical objects or concepts. The model builder selects from a palette of icons to construct the objects required to describe the system, such as reservoirs, streamflows, releases, and demands. When the basic system configuration is defined, the modeler then defines system operating policies and provides site specific information such as streamflows, demands, and economic impacts.

The specific computer program used to implement water resource system models developed in the National Drought Study is STELLA II®, produced by High Performance Systems of Hanover, New Hampshire. STELLA II® grew out of a need for better simulation languages for use in business and academics. The first copies of STELLA II® were shipped in late 1985. STELLA II® is most simply described as a visual spreadsheet for systems analysis where the process being modeled can be presented as pictures as well as equations. STELLA II® is one of many object-oriented simulation modeling environments available commercially. STELLA II® was selected over other available software because of its unique combination of simplicity, power, and cost-effectiveness.

This shift in modeling paradigm raised a number of issues that were addressed in the National Drought Study and which will impact computer usage in the future.

Issue 1: When are computer models appropriate for drought planning?

The development of tactical and strategic drought plans requires carefully defining the objectives and constraints of stakeholders and decision makers in a region, evaluation of the status quo, generation of alternatives, and selection of alternatives based upon the objectives and constraints. Although these tasks can be accomplished without computers (as they often were in the past), planners can be aided significantly by developing computer models. Such models allow planners to evaluate a larger number of variables and more complex relationships than would otherwise be possible. Computer models allow planners to incorporate important information and data such as long streamflow sequences, hydrologic and hydraulic concerns, economic impacts, biological impacts and other concerns. Computers allow large amounts of information and data to be efficiently organized and retrieved, and perform calculations quickly.

Issue 2: What is a "shared vision model"?

The term "shared vision model" is used to describe a model constructed in a process in which stakeholders and decision makers work cooperatively to include factors and elements of interest to them. It can be contrasted with modeling efforts in which a small number of technical experts develop models without truly considering who will use their model and how it would be used. The construction of shared vision models requires computing environments that are extremely user-friendly and easy to learn, yet powerful enough to capture interactions between the elements being modeled.

Shared vision models allow stakeholders and decision makers to better understand a water resource by cooperatively developing and exploring management alternatives. These models provide a computing environment in which model assumptions can be easily understood and modified, impacts of decisions can be evaluated, and alternative futures can be explored in real time. They allow stakeholders and decision makers to influence the planning and modeling process from the outset and to share their understanding of resource management. When a shared vision is created, inaccuracies, improper assumptions, and misconceptions can be identified, thus preventing their incorporation into the planning process.

Issue 3. When should "shared vision models" be used?

Shared vision models should be used in every important water resources evaluation where there is a gap between what stakeholders and decision makers need to know and what they are capable of learning from specialized models and databases that address parts of the decision domain. Drought planning today requires the consensus of an ever growing number of often competing and conflicting interests. A key to successful water resources planning and management is to assemble individuals representing these interests, generate agreement on which problems to address, and then develop ways in which the status quo can be improved. Shared vision models provide an ideal tool for this process. Other characteristics that suggest the use of shared vision models in water planning include the need to: gain the confidence of stakeholders and decision makers; provide a productive negotiation environment to aid in resource planning and allocation; obtain detailed information about resource operation and management; convey technical information to a large number of non-technical participants; and develop, document, and maintain a dynamic and flexible vision of resource management.

Issue 4. How are shared vision models developed?

The experience generated during the National Drought Study suggests that a variety of approaches to building shared vision models can work. The approach that was used in the Green River DPS typifies the process.

- First, stakeholders and decision makers who would be impacted by the DPS effort were identified. These individuals pointed out problems in the region, the institutions and individuals that were responsible for addressing these problems, and constructive steps that could be taken to address the problems. These problems were then translated into study objectives.

- Training in model construction was provided to individuals representing the stakeholders and decision makers. This training occurred in two steps: instructors traveled to each DPS site to introduce basic modeling concepts and a week long workshop was held introducing more advanced topics.

- Interviews were conducted with each agency representing stakeholders and decision makers. At these interviews, participants were asked to define their role in water management and their relationship with other agencies. They were encouraged to define their particular uses of models and describe how models could benefit their agency.

- Based on these responses, a prototype model was constructed. When the prototype was complete (including the concerns of stakeholders and decision makers), this model was demonstrated to each group. Modifications to the models were made to incorporate the comments and suggestions.

- Finally, a group workshop was held to demonstrate and test the model and to ensure that the interests and concerns of the affected parties were contained in the model.

Issue 5: What are the potential liabilities of shared vision models?

A concern of some stakeholders and decision makers associated with the National Drought Study was that shared vision models could be misused by groups or individuals. Because the models are easy to use and to modify, results generated by altered or "infected" models could be used to misinform the public or to obscure the true implications of water management issues. Although these concerns are real, a purpose of developing a shared vision model is to include a wider range of individuals in the planning process and to increase the level of understanding of all parties. To limit access significantly would reduce the value of the model. Instead, the model would be distributed to all interested and appropriate parties, but with access to the model would come responsibilities.

A number of potential actions were suggested in the National Drought Study to address these issues. First, a partnering agreement should be developed by affected parties regarding model use and distribution. A single agency should be responsible for model distribution and maintenance. This agency should be viewed by all party members as unbiased and technically competent. Permanent changes to the model would occur only when the stakeholders and decision makers agreed that the changes allowed a more accurate representation. The model would be reviewed at frequent intervals to ensure its appropriateness and correctness and new versions distributed. Procedures should be developed to provide guidance on interpretation of model results. Interpretation of model results for consumption by the general public or press should be coordinated with all members of the partnering agreement. Parties not respecting the agreement or using the model in an unconstructive fashion would lose access to the model.

Issue 6: How do shared vision models interface with existing models?

Shared vision models, such as those built with STELLA II® in the National Drought Study, will not replace many of the existing models used for water management. In professional settings dealing with public projects and public impacts, many important issues remain that must be evaluated by experts and for which public debate can add little. A role will remain for less user-friendly models that address specific technical issues and whose results and implications do not need to be explained to non-experts.

However, many important questions must be addressed in a more public forum and the development of shared vision models must facilitate the necessary public debate. The output of more conventional models may well prove valuable as input for shared vision models.

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D - WATER LAW AND DROUGHT

A drought preparedness study, which includes joint action by Federal, state and municipal agencies, necessarily involves a complex legal context. This context includes not only the major types of water law differentiated between the eastern and the western states, but the cases where the river basin in question comprises states using both systems. Also, it includes conditions of water management not only during normal times, but also during times of drought emergency, when, in many states, emergency powers of some agency of government may become effective. Drought planning must start with a tentative assumption that the existing legal structure will continue; but if circumstances warrant, changes in law may be recommended. Water law is changing and evolving across the United States. Some tendencies of change in applicable law are noted in this annex and may suggest the desirability and practicability of change in any particular case.

Water law to be taken into account includes constitutional and statutory provisions of both Federal and state judicial decisions and municipal ordinances.

Basic Systems of Water Law

There are two basic water law systems in the United States: the riparian law theory which prevails east of the 100th meridian, and the prior appropriation system which predominates in the west. Some western states have systems which combine elements of the riparian doctrine in their prior appropriation systems (California is the most familiar example). These are called hybrid water law systems. Emerging in the eastern United States is a system of water use permitting which might be called regulated riparianism, and which represents the trend in water law development in the east. It provides for the allocation of water use privileges by the state, superseding the original rights of riparian owners. More than half of the eastern states now have a regulatory permit system.

The prior appropriation system is simple in principle, but rigid in application, particularly with respect to drought conditions. If an appropriator is junior, he will lose his water in favor of the senior, with no consideration given to the value to society of the use of the water. As water needs change, the strict prior appropriation doctrine does not work well to accommodate new or better requirements. Also, how do we deal with water uses which need no diversion, such as instream flows? Further, the basic appropriations systems does not encourage water conservation, since water rights not fully used may be lost. However, despite these deficiencies, the water rights of users are so firmly established in the western states that it is only with great difficulty that any changes are initiated.

Site Specific Programs

The trend of water law both in the east and the west is to apply new, improved approaches to specific geographic areas, where problems are sufficiently obvious to warrant political action. In Virginia, recent statutes allow the State Water Control Board to designate management areas within which restrictions may be imposed to meet emergency conditions. Indiana, North Carolina, South Carolina and New Jersey allow restrictions on groundwater use in specific areas. In the west, the Arizona Groundwater Management Act establishes special use restrictions in certain areas.

Quantification of Water Allocations

Some western states are taking steps to adjudicate existing water rights in order to determine how much water is really needed. A large source of uncertainty regarding water use comes from unquantified claims of the Indian tribes and certain Federal reservations. Some western states are encouraging the transfer of water rights to provide for more efficient use of water during time of drought. However, water management during drought should not be limited by an assessment of legally recognized water allocations. Water managers should push for flexibility of water use where needed during drought, without waiting for adoption of basic improvements in water allocation systems statewide.

Public Trust Doctrine and Instream Flows

The full extent of the public interest in water is not always recognized by water allocation decisions. The public trust doctrine holds that the sovereign retains control of the water resource to serve public trust purposes, which may include recreation and ecological values. The public trust doctrine has been explicitly recognized in some form in nine eastern and western states. In California, a court decision requires California water managers to take the public trust into account in planning and managing water resources. As a practical matter, any drought management plan must include consideration of the instream values of water, in order to avoid a challenge based upon the public trust doctrine.

In most states, instream flows are, to some extent, explicitly protected. A 1989 survey lists eight western states with instream flow laws, and four which protect instream flows by means other than allocation. In the east, many states have authorized agencies to establish minimum stream flows or water levels. Instream flows must always be considered as an important factor in drought management planning, particularly as the drought intensifies.

Water Conservation

The term water conservation refers to methods of reducing consumption of water (although in the west the term traditionally means conserving seasonally available water by dams and reservoirs).

Water conservation is an essential tool of drought management. The prior appropriations allocations procedure discourages water conservation to the extent that water not put to beneficial use may be lost. A few western states have laws which favor water conservation, by use of water salvage, water marketing or water banking; but sixteen eastern states have legislation recognizing the need to conserve water supplies.

Transbasin Diversions

The diversion of water from one basin to another is almost always controversial, whether in the east or the west. Such proposals relate primarily to long-range water planning rather than to drought management. However, during a severe drought, if the necessary facilities exist and the state law allows, temporary interbasin diversions may be authorized to meet the needs of the most severely affected areas.

Groundwater Law and Conjunctive Use Management

In most states, allocation of ground water is handled differently from that of surface water. In some states there is no provision at all for state allocation of ground water. This situation complicates the preparation of drought contingency plans, which, in principle, should provide for most effective use during times of drought of ground and surface water combined, or conjunctive use. Only two states in the east have expressly provided for surface and ground water resources to be managed as a single system. Arizona has a broad-based centralized program of ground water management, which was devised to meet a chronic and continuing ground water shortage. New Mexico has a system of prior appropriation for ground water resources. The main development of conjunctive use management in the west has been on an incremental, site-specific basis, rather than a statewide program, especially in California. To meet the difficulties caused by the recent drought in California, a water bank was organized to facilitate water transfers from willing sellers to water districts in need. Loans are used to allow water districts to develop new supplies, including new wells devoted to augmenting stream flows. In the Orange County Water District in California, the District chose not to regulate ground water withdrawals directly, but to impose fees and use the money to import new water.

It is apparent that the control and management of ground water by the different states is highly diverse. In most respects, the physical and institutional arrangements for handling ground water are relatively difficult to modify when a drought occurs. Drought management studies must be framed in the context of existing arrangements. However, changes may be recommended in advance if the potential drought situation forecast on that basis appears to be too unfavorable.

Conclusions

Drought management planning requires full information in reference to legal authorities and restrictions, including knowledge of changing trends nationally, which may suggest particular changes that might improve drought conditions. If the situation is sufficiently serious, changes in law may be recommended.

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E - ENVIRONMENTAL EVALUATIONS: KEY ISSUES FROM THE CASE STUDIES

During the case studies and support studies conducted as part of the National Drought Study, a few issues regarding the evaluation of the environmental impacts of drought response plans frequently caused debate. This annex discusses those issues and provides some suggestions as to how they might be addressed.

Issue 1: The use of the status quo in the management of environmental impacts during drought

In the study of the feasibility of a federal reservoir, the definition of what is referred to as the "Status Quo" in the DPS method, or the "existing conditions and most probable future without a Federal plan" in federal planning guidance is clear: the basin without a federal reservoir. All changes in the basin that are expected to occur outside the federal action are included in this scenario. The definition of that baseline isolates the effects that will be generated by the recommendations of the feasibility study from the effects from decisions made outside the feasibility study. This evaluation approach is widely understood and accepted.

But during the National Drought Study case studies and in other forums in which National Drought Study members participated, there were many debates rooted in the definition of the status quo for tactical responses. Many believed that environmental demands for water during drought should be tempered by the fact that without the reservoirs, the natural system would have had even less water. Because the natural condition was no reservoir, they argued, this should be the status quo for the environment, and water beyond that should be considered an improvement.

But the "status quo" is merely the situation that would occur if the recommendations of the DPS were not implemented, and that meaning applies no matter what type of impacts are being considered. In this example, the status quo would be defined by the current operation of the reservoirs. The environmental impacts of alternative plans should be compared to the status quo.

Issue 2: The limits of knowledge on the environmental impacts of drought

Environmental impacts become harder to measure the longer the period of analysis and the farther from the stream. A short term drought might affect one breeding cycle, or destroy a segment of a population of animals or plants. These impacts are well known; they are the familiar subject of most drought planning efforts. The greatest difficulty lies not in identifying the impacts, but in instituting the solutions and the necessary trade-offs among interests.

Medium and long term droughts (longer than one year) have environmental impacts which are harder to identify. As a result, defining the mitigating effect of a set of management measures is equally difficult. In addition, medium and long term drought conditions present issues of cumulative impact which are poorly understood. For example, what will be the cumulative impact of a drought which hinders fish spawning for an entire generation of fish? Similarly, what will be the cumulative effect on the environment of changes in land use, human population and pollution, and how will severe drought affect this changing status quo? Such problematic questions have led some to suggest "adaptive management" guided by large scale system-wide controlled experiments (Holling, 1978). This is a recognition of the lack of knowledge about the long term effects of human intervention in natural systems. The unknown environmental impacts of medium and long term drought could be candidates for such an analysis. (For a discussion of cumulative impact analysis, see Stakhiv, E., “An Evaluation Paradigm for Cumulative Impact Analysis,” U.S. Army Corps of Engineers: IWR Policy Study 88-PS-3, 1988. Stakhiv differentiates accumulating impacts of human actions (the impacts of taking a number of small, incremental actions) from the multiobjective planning perspective where the cumulative effect of a number of factors is considered.)

Issue 3: Multiobjective analysis of changes to an ecosystem

The same physical changes (for example, reductions of instream flows) induced by water management decisions may have impacts in the economic, environmental, and social well being accounts. Trading across accounts is not impossible, but (by definition) no common currency exists for the three accounts.

Reductions in instream flows can reduce ecosystem based recreation, creating an economic impact which can be given a dollar value and potentially traded for other economic impacts. For example, studies have investigated a process for determining how much sport fishermen would be willing to pay for a healthy fishery (Olsen, 1992). Other kinds of outdoor recreation activities, such as boating and swimming, can also be valued in monetary terms. These are elective activities for which individuals are willing to pay. Their decision to recreate at a stream or lake is, to a great degree, a consumer’s decision about how to spend time and money recreating. Thus, the effects of changes to these recreational opportunities are essentially economic.

The suspension of cultural traditions is considered a social effect. Tribal fishing customs which call for taking fish in a particular way at a certain time of the year embody fundamental, self-defining values for the tribe. The fishing may have religious and cultural components as a ritual time when families reunite. This fishing is more than recreation, and should be accounted for accordingly.

The same reduction in flows may also affect the health of the natural ecosystem, and these effects should be tracked as environmental impacts. Though methods have been used to reach a ‘nonuser’ inherent value for the existence of a natural resource by using survey techniques (Olsen, 1993), the willingness of society to pay for environmental health is most often determined case by case *after* a trade-off across accounts has been made. For example, if society forgoes $1,000,000 in hydropower benefits to save a pair of nesting birds, then we can say after the fact that there was an implied economic value in preserving that pair.

Each of these three impact areas is likely to have individual proponents. Alternatives which mitigate recreational impacts may not address the concerns of environmentalists or tribes.

The three examples show that though instream flow seems to be a common denominator, the three interests are fundamentally different in economic, social, and environmental terms. Actions which are directed at one interest may not be viewed as appropriate by other interests.

F - ECONOMIC EVALUATIONS: KEY ISSUES FROM THE CASE STUDIES

In each of the Drought Preparedness Studies there was a debate about whether and to what extent economics could be used to develop and evaluate alternative plans. The issues most frequently raised in the case studies are examined in this annex.

Historically, economic analysis has played a minor role in the formulation and evaluation of plans to mitigate or avoid the impacts of drought. This is a result of:

- the difficulty in defining and describing a drought event in terms of recurrence interval and spatial and duration characteristics;
- the lack of reliable information from previous droughts;
- the limitations of available analytic tools that are available;
- the nature of tactical drought response plans, which tend to include a variety of non-structural measures by more than one agency;
- custom. The use of economic analyses in the evaluation of federal water projects, where it is now required, evolved over a period of decades and was spurred by critical reviews of federal policy by experts outside the federal government. Regional drought responses have not engendered the same sustained criticism.

Issue 1: Should the evaluation of alternative drought contingency plans include consideration of economic impacts?

The second step of the DPS method (Chapter 4) is to develop planning objectives, decision criteria, and measures of performance. It is during this step that this question should be answered. DPS teams should ask themselves:

- if economic efficiency or the equitable distribution of economic impacts are goals of regional water management;
- whether alternative plans could increase economic efficiency or effect more equitable distribution of economic impacts;
- whether the measures of performance of competing alternatives favor different stakeholders (for example, one alternative increasing days of lake recreation, the other, rafting).

To the degree that their answer to these questions is “yes”, the DPS teams are affirming that economic assessments will be necessary to determine which plans best meet their goals. The team must then decide *how* to conduct the assessment, considering the generic problems listed at the beginning of this annex, the interest of decision makers, study funding, and institutional barriers to implementing economically efficient alternatives.

Issue 2. What is a benefit-cost analysis?

Benefit-cost analyses evaluate the preferences of individuals, backed by their willingness to pay, for the outputs of a water system as compared to their preferences for the resources used to provide those outputs (Major, 1977). In strategic water resources planning, those choices are often between water and non-water investments. In a drought, the choices will often be between using water for one purpose or another, or using water now rather than saving it for later use.

Those preferences are most visible in a market situation, where individuals are free to determine the level of resources they will exchange in return for specific outputs. In that case, the economic benefit society reaps from a set of transactions is the sum of the consumer and producer surplus from those transactions. The following simplified example (illustrated in Figure F-1 and Figure F-2) shows how benefits would be calculated in a market driven allocation of water.

If hydropower producers can get all the water they want (20 million acre-feet), and they are willing to pay $100 million for it, the area under the *demand* curve:

½ X ($10/acre-foot) X (20,000,000 acre feet)

Water providers will accept no less than $100 million (the area under the supply curve) for 20 million acre-feet, presumably because someone else besides hydropower producers will pay them that much for the water.

The optimal amount to allocate is where the two curves intersect, at a price of $5 an acre-foot, and a quantity of 10 million acre feet, a sale worth $50 million. This is depicted in Figure F-1. Power producers would have been willing to pay $75 million, and water suppliers willing to accept $25 million (the areas under the demand and supply curves from 0 to 10 million acre-feet).

Consumer surplus is the difference between what power producers were willing to pay and what they did pay ($75-50 = $25 million). *Producer* surplus is the amount of money water suppliers received ($50 million) minus the amount they were willing to take ($25 million) = $25 million. Hence the economic benefit from this transaction is $50 million. Producer surplus is an increase in seller's income and a decrease in consumer's income. The gross value of the water to society was $75 million, the buyers total willingness to pay, but there was a $25 million opportunity cost to achieve it. Total surplus is the sum of consumer and producer surpluses.

A drought would move the supply curve up; water suppliers would ask for a higher price per acre-foot for a given volume of water. In Figure F-2, the optimal solution is the sale of 8 million acre-feet of water at $6 an acre-foot, a sale of $48 million. The sum of consumer and producer surplus is now $30 million (½ * $(10-2.5)/Acre feet* 8 million acre feet), so the economic effect of the drought under the status quo is $20 million ($50-$30 million). If an alternative plan could be developed that produced a consumer surplus of $40 million during a drought, a benefit of $10 million could be attributed to the plan.

Estimating changes in economic benefits in non-market conditions. However, markets may not capture all economic effects if some costs or benefits are not accounted for by producers or consumers. Moreover, many water transactions are not driven by market forces. In those cases other methods for estimating the economic benefits of one plan versus another must be used. There is extensive literature on the estimation of economic effects in non-market conditions. The P&G include a comprehensive set of procedures for the full range of water purposes, and these are summarized below. DPS teams may face situations in which the P&G estimates are not acceptable to decision makers who nonetheless are interested in estimating economic impacts. In those cases, teams should call an expert for help. Sources include the Corps Institute for Water Resources, and Waterways Experiment Station. In addition, experts can be found through state water resources research centers.

The P&G has step by step measures for estimating benefits in each of several purposes.

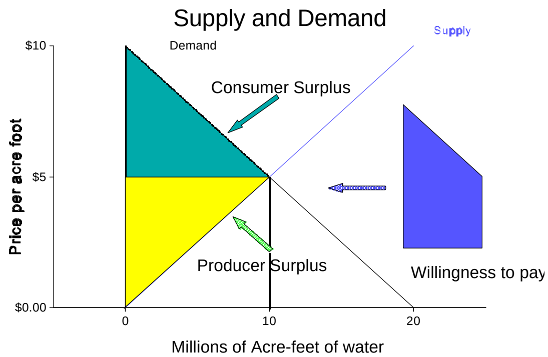

FIGURE F-1. ECONOMIC BENEFITS FROM MARKET TRANSACTIONS

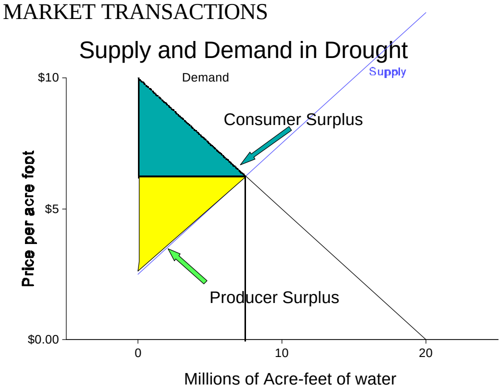

FIGURE F-2. IN A DROUGHT, CONSUMER AND PRODUCER SURPLUS ARE REDUCED BY $20 MILLION.

Although designed to be used primarily in the calculation of NED benefits, they are also

useful for estimating RED

benefits - only the area of measurement changes. In the federal accounting system, economic impacts (which track the distribution of effects) such as employment are also included in the RED account. Because employment is not a component of economic efficiency, these RED impacts cannot be calculated directly from RED benefits.

A full presentation of how to use the P&G four-account method in drought planning is available in Drought Impacts in a P&G Planning Context (NDS-8). Additional information can be found in National Economic Development Procedures Manual - Overview Manual for Conducting National Economic Development Analysis, October 1991 and National Economic Development Procedures Manual - National Economic Development Costs, June 1993.

Issue 3: How can the economic impacts to agriculture be measured when irrigation water is provided at a subsidy or the sale price of crops is subsidized?

It is very difficult to measure the true economic impacts of changes in the allocation of water to farmers when the price of water and crops are both subsidized. The existence of double subsidies itself may be an indication that no significant *national economic* impacts will occur. But DPS teams should consider regional economic effects if that is a decision criterion.

Agriculture is the sector of the economy that is most frequently and severely affected by drought. Water is a critical input in agricultural production. Drought-related crop losses result from dry soils, dehydration, impaired productivity of the land, insect infestation, and increased incidence and spread of plant disease. Wildlife, denied their natural forage, graze on and damage agricultural crops. When perennial crops, like vines and fruit trees, are damaged by drought, the impacts can last beyond the drought.

With drought impacts comes a reduction in agricultural income and jobs. Losses in agricultural income are RED losses. Whether these impacts are NED losses (whether the loss of crops in one region decreases the national supply of agricultural products, reducing American society's total surplus), depends on the severity, duration and extent of a drought and the uniqueness of the crop and its growing

area. If drought occurs at a point in time that
precludes offsetting increases in production

TABLE F-I. THE METHODS PRESCRIBED IN P&G FOR ESTIMATING THE ECONOMIC EFFECTS OF WATER MANAGEMENT IN NON-MARKET CONDITIONS.

Purpose:	**the economic effect of a shortfall can be estimated by:**
Municipal and industrial	the cost of making that shortfall up with the cheapest alternative source, including conservation.
Recreation	changes in willingness to pay estimated from contingent value surveys or the travel cost method, or, (if required supportive information is not available), from the decline in use times a pre-determined unit day value of recreation times the change in use. In any case, DPS teams must agree on a function that relates stage or flow to the value of the recreation experience.
Power	the cost utilities pay to replace that power, and (if this is an institutionalized plan that will adjust firm yields) costs to construct additional capacity.
Navigation	the additional cost of transporting the goods by rail and truck that could not be shipped by boat because of inadequate depths.

from other regions, the effects are more likely to be NED effects. Net farm revenue (income minus costs) may be an important measure of the effectiveness of drought response plans to affected farmers. When estimates of the economic impacts of agricultural shifts are unlikely to be meaningful, agricultural stakeholders and DPS teams should consider *not* developing agricultural economic estimates, while still using other measures of performance, such as changes in acreage planted, gross revenue, or farm employment to compare the acceptability of alternative plans. The limitation of these measures is that economic tradeoffs must be made without reference to agriculture.

Issue 4: Are the NED impacts from drought likely to influence decisions on the construction or operation of a federal reservoir?

This question can be best answered if considered from a strategic and tactical viewpoint (Table VIII describes these terms). In strategic planning (such as feasibility studies of new projects), the economic impacts of drought are at least theoretically considered in the plan selection process. In tactical responses, NED impacts are an important, but not the only, consideration in determining how federal reservoirs will be operated.

Federal studies of the feasibility of *strategic* water resources measures require the estimation of NED effects. Unless an exception is granted, the alternative recommended in such a study must be the one that reasonably maximizes net NED benefits, and the net benefits must be greater than zero. This alternative is then referred to as the NED plan.

As a rule, if the objective is to provide more reliable water supply for any purpose, the NED plan will increase supply reliability but will not provide certain supply. By definition, the size of the NED plan is selected when the marginal benefits equal marginal costs; the next increment of reliability will not be worth the incremental costs required to provide that reliability. If in the NED plan, for example, a navigation and water supply reservoir is built, it is safe to assume that in a fairly rare dry period, the reservoir will not be able to meet unconstrained demands for water. This is exactly the definition of a drought in a managed water system.

Theoretically, then, federal projects are sized to eliminate those drought impacts for which it is cost efficient to do so, and to leave the rest to be attenuated by *tactical* plans, including drought contingency plans for reservoirs. Of course the implied precision of this optimization is misleading, because potential impacts are projected over a 50 to 100 planning period, and assumptions about the severity, duration, and frequency of droughts are simplified so that the calculations are manageable.

The situation is quite different in the development of a *tactical* plan that specifies how a federal project will be operated during a drought, or in the evaluation of specific decisions by federal reservoir managers during a drought. In that case, NED losses are important, but are not the only criteria in determining federal actions. Corps managers will also consider applicable laws and contracts, and whether there are substitute for the output from the Corps reservoir (such as thermal power to replace hydropower).

Issue 5: Droughts last for months, even years. How can the impacts of drought be distinguished from impacts caused by socioeconomic changes?

The first question planners should ask is whether they need to determine what the impacts of the drought were or how alternative responses could reduce impacts. The second answer is usually sufficient and easier to estimate.

Isolating the effects of a drought from other economic activities that may be occurring simultaneously is very difficult. The attempt to measure these effects during the recent California drought and recession (NDS-5) illustrates this difficulty.

Commercial/industrial surveys were developed and administered by the California Department of Water Resources (DWR) during 1991/92 in part to identify the impacts of drought on California's commercial and industrial sectors. These surveys included telephone and mail surveys, newspaper article searches, and the review of other surveys conducted by water agencies and business associations. The purpose was to identify the specific businesses affected by drought and to gain a better understanding of how they were affected.

It was hoped that the results of this research could be appropriately extrapolated to the entire business community. Impacts, identified during the survey, were to be used with the DWR input-output models to identify direct and indirect changes in regional income and employment. With very few exceptions, the commercial/industrial survey did not discover significant drought effects on businesses, and the proposed extrapolation and input-output analysis were not conducted.

Other surveys were conducted during the same time period by twenty-four (24) water agencies and thirteen (13) chambers of commerce. The results were mixed. Many indicated loss of revenues, layoffs, and impacts from moratoriums on new water connections. The interviewees, however, did not aid in determining how much of these impacts were due to drought and how much was due to recession.

But in general, only the *incremental* economic effects of alternatives, as compared to the status quo, are important in a DPS. These are somewhat easier to define and discern.

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G - HYDROLOGY

Fundamental Principles

This discussion of drought hydrology is limited to consideration of droughts with durations of one month or more. While much of what is said could also be applied to durations shorter than one month, some factors come into play for durations of less than a month that fall outside the scope of this discussion. These differences relate primarily to soil conditions, interception, and movement of water through channels.

To a surface water hydrologist, drought exists when any of several parameters, such as streamflow, precipitation, and soil moisture, are in the lower region of their frequency distributions. To a ground water hydrologist, the water table elevation may be the parameter of concern. To a water manager, reservoir contents may be the important factor in hydrologic analysis.

The physical system and its inputs and outputs give rise to the frequency distributions referred to above. ln the usual depiction of the hydrologic cycle, precipitation falls to the earth or on vegetation; is intercepted, infiltrated, evaporated, or runs off; and moves through or across soil and rocks to the stream system which ultimately carries the water to the oceans, where it evaporates to complete the cycle. When precipitation falls as snow, it may remain in the snow pack until enough energy has been absorbed to cause it to melt, after which it moves through soil, rocks, and streams as described above. In drought conditions, discontinuities or abnormal behavior can be seen in the hydrologic systems. Actual evapotranspiration will usually be lower because of the reduced amount of available soil moisture. (Potential evapotranspiration may be higher, if the drought conditions are accompanied by higher than normal temperatures and winds.) Interception is eliminated or reduced because of reduced precipitation. Infiltration may be altered because of soil surface conditions.

Measurement of streamflow during both high flood and drought conditions tends to be more difficult and less accurate because of poor definition of the rating curve and inaccuracies in measuring stage. In drought conditions, these problems are exacerbated by the increased importance of small diversions from the stream above the gage. As a consequence, the precision of measured low flows is likely to be lower in percentage terms, except during periods when streamflow is zero.

Length of Streamflow Record and Procedures for Adjustment and Augmentation

The conventional wisdom is that the longer the record length, the better. This premise is based on an assumption that the longer record better defines the frequency distribution. In the Drought Atlas, we have calculated distributions based on the entire length of record, in accord with that assumption. For a first approximation, it is probably not unreasonable. However, some factors have been ignored that a hydrologist should take into account in preparing analyses of streamflow for a particular situation.

A longer record will define a distribution better than a short record only if the distribution does not change during the period. Such conditions are likely in watersheds that have not experienced major changes in land use, diversions from or into the watershed, or changing errors in gage measurements. There are watersheds like this in the United States, but not all gages meet these criteria. Stream gages are often placed on streams where water resources development is anticipated or where water management decisions are influenced by streamflow information. These tend to be the kinds of locations where land use changes and watershed diversions are likely. If a longer record doesn't necessarily guarantee higher accuracy, what steps should a hydrologist take to prepare accurate analyses? The general approaches available are as follows:

- Determine what portion of the streamflow record is sufficiently representative of current conditions to use in the analysis;

- Use the measured streamflow record for frequency and other hydrologic analyses without augmentation, and with or without adjustment;

- Compare the existing record with nearby longer-record stations considered to be in the same hydrologic regime, and adjust or extend the existing record accordingly;

- Generate an augmented streamflow record from recorded precipitation and one or more precipitation-runoff models;

- Generate synthetic flows by statistical procedures from the portion of the record considered representative of current conditions.

Determining what portion of the streamflow record is representative involves both qualitative and quantitative analysis. The qualitative analysis is a review of watershed history to determine whether there have been significant changes in land use or land cover. The principal dimensions of the quantitative analysis are examining the diversions of flow into and out of the watershed, and evaluation of the rating curves and station location changes.

Among the possible outcomes of this analysis are conclusions that:

- The changes are so significant that only the most recent portion of the record can be used;

- The changes over part of the record were sufficiently minor that these portions of the record can be used along with the most recent record; or

- Even though the changes were significant and definitely affect record quality, the alternatives for augmentation and adjustment of the record are inferior. Adjusting the existing record is likely to be superior to the alternatives. This is most likely to be useful where the principal effect on the record is flow diversion. The effects of land use changes are harder to estimate, because they involve changes in evapotranspiration and timing of runoff. It should be possible, however, to estimate at least the direction of these changes.

Using the measured streamflow record without augmentation is the standard approach used by hydrologists. It can be enhanced by certain statistical analyses. For frequency analysis, the best available methods use the L-moment procedures used in the National Drought Atlas. The accuracy of such parameters as the mean, median, and measures of variance can be estimated more precisely by a procedure known as bootstrap analysis, in which the recorded values in the streamflow series are repeatedly sampled, with replacement, and these parameters are calculated from the resulting synthetic series.

A particular issue in dealing with streamflow during drought conditions is that there are situations in which streamflow is consistently below or above normal for a decade or more.

If most of a streamflow record occurs during such a period, the record may not be as representative as it should be for accurate drought analyses.

The practice of comparing a record with a longer record on a nearby stream is widely used by hydrologists. In principle, this is a reasonable procedure. In practice, one must decide which nearby streams, if any, have a hydrologic regime similar to the one in question.

At best, objective measures and procedures are used to make this determination. The measures used include such things as similarity in basin geology, similarity in annual or seasonal precipitation, similarity in timing and distribution of flow, and similarity of moisture sources. Double mass curves and statistical correlations may be used to help decide whether another record should be considered sufficiently similar to merit use in record extension (Linsley et al., 1982, p. 117).

The value of augmenting a streamflow record with precipitation-runoff models is predicated on the assumptions that a) precipitation is influenced less by land use changes than is streamflow, and b) that reliable relationships between precipitation and streamflow can be developed. The first assumption is nearly always a good one, and tends to be better for large areas than for small ones. The second assumption is essentially empirical in nature and models of these relationships can be developed to different degrees of approximation.

The simplest relationships between precipitation and streamflow at time scales of one month or more are statistical correlations or graphical relationships (Linsley et al., 1982, pp. 254-256). Such relationships are relatively easy to explain to a non-hydrologist. In these relationships, precipitation is the independent or predictor variable and streamflow is the dependent or predicted variable.

Comparable data series of precipitation or streamflow are prepared and either plotted on graphs or subjected to a statistical correlation procedure. The relationship could be a simple linear or curvilinear relationship, or one in which one or both variables have been transformed, often by a logarithmic transformation.

Additional variables may be added to improve these relationships. For example, instead of relating this month’s precipitation to this month’s streamflow, one could use two predictor variables, such as this month’s precipitation and last month’s precipitation. Such a practice would recognize the importance of antecedent conditions that influence soil moisture. Other variables that might be included are monthly mean temperature or measured soil moisture at an index station.

In watersheds where streamflow depends upon snowmelt, regional or watershed relationships between such predictor values as snowpack indices, temperature and predicted streamflow have usually been developed and would be used to estimate streamflow (Linsley et al., 1982, pp 256-258).

A more deterministic approach to estimating runoff from precipitation is to use a water balance that includes major components of the hydrologic cycle. This approach has been used by Thornthwaite and Mather at scales ranging from the entire earth to individual small watersheds. At its simplest, an estimate of actual monthly evapotranspiration is made by using a procedure proposed by Thornthwaite and Mather. The procedure first estimates an unadjusted potential evapotranspiration as a function of temperature. These estimates are then adjusted for day length, which is expressed as a function of latitude. The equations use a formula in which the principal variables are monthly mean temperature and day length. Estimates of soil moisture retention capacity are then made for the area under analysis. Then, using a spreadsheet format, potential evapotranspiration is subtracted from monthly precipitation. The monthly deficit or surplus is then used to calculate the monthly change in soil moisture storage. In months when precipitation exceeds potential evapotranspiration, actual evapotranspiration is considered to be equal to potential evapotranspiration. Runoff is calculated as half of the surplus water in each month (Mather, 1978).

The Thornthwaite-Mather approach is crude in its estimates, and somewhat difficult to follow in applying it. High precision cannot be expected. However, it has the advantage of being usable with a minimum of information, and can be regarded as a suitable first approximation, if no other rainfall-runoff model has been developed. If more elaborate and well-tested models have been developed for a watershed, they should, almost without exception, be employed instead of the Thornthwaite-Mather approach.

More complex precipitation-streamflow water balance models are based on simulations that use time steps shorter than one month, and calculate values for several of the variables in the hydrologic cycle. Typically, such models use short-period precipitation (one day or less), daily temperature, and land use characteristics to estimate evapotranspiration, soil moisture at one or more levels, and volume of streamflow. Timing of streamflow is based on travel times through the soil, over land, and in the channels (a function of stream channel characteristics). Such models have the potential to provide highly precise and accurate simulations of streamflow, where there is considerable information on the input parameters. However, even in those instances where minimal information is available, such as precipitation and temperature, these models can provide good estimates for durations of one month or more. For practical applications, the results may often be as accurate as they need to be to make water management decisions (Linsley et al., 1982, pp 339-356).

HEC-1 is one of the most widely used and most complete models for relating streamflow and precipitation (Bedient and Huber, 1992). It is event based, and would require adjustment of monthly values derived from the *Atlas* to obtain the short duration events necessary as input to the model.

Generating synthetic streamflows by statistical procedures has been done since the 1960's, and precursors of these procedures have been in use since the 1920's. Statistical synthetic hydrology was impractical before powerful digital computers became available in the 1960's, because of the large amount of calculation required. The earliest methods involved writing numbers that represented single items in an existing data series on cards and repeatedly shuffling and drawing from these cards to generate synthetic data series of streamflow. The methods in use now work from the existing distribution and randomly generate many new sequences from that existing distribution. The existing distribution may be represented by parameters of the distribution or, alternatively, the measured values may be repeatedly sampled to develop long series, as was done in the bootstrap analysis, described above (Linsley et al., 1982, pp. 388-411).

A particularly effective modelling approach for forecasting "streamflow volume over a long-term (seasonal) duration and a short term (5-90 days) duration and providing associated probabilities of occurrence and statistical evaluations of the predictions" is the National

Weather Service Extended Streamflow Predication Procedure. This procedure has been tested for several years in different parts of the country, and has yielded useful forecasts.

The Extended Streamflow Prediction Procedure (ESP) uses historical meteorological data and assumes that each year of historical data is a possible representation of the future. ESP forecasts use the National Weather Service River Forecast System Operational Forecast System, which "generates short-range streamflow forecasts by inputting observed and forecast precipitation and temperature data into conceptual hydrologic and hydraulic models that simulate the snow accumulation and ablation, rainfall/runoff, watershed routing, and channel routing processes to produce simulated streamflow." (Day, 1985).

While the ESP procedure uses historical traces of meteorological variables, it would also be possible to use elements of the procedure with precipitation amounts derived from the National Drought Atlas. Among the difficulties faced in using monthly precipitation with the conceptual models for relating rainfall and runoff in the NWSRFS Operation Forecast System is estimating shorter duration precipitation from the monthly values. A summary of some of the approaches to making these short duration estimates is given by Essenwanger (1986).

It is tempting to think that the inherent inaccuracies of making runoff estimates are so high that there is little point in doing them at all. This temptation should be resisted. The point of making estimates is to make decisions. Those decisions often entail setting upper and lower boundaries on the expected future state of a system at a given probability of occurrence. If the lower bound is zero, and the upper bound is also near zero, higher precision will not enhance the decision. If previous practice was to make worst-case estimates, e.g., the lowest flow ever recorded for the subsequent month or year, and one can establish that the upper and lower boundaries on expected flow are materially different from the worst-case estimate, the decision has been improved. Because drought flows and drought precipitation values are at the low end of the frequency distribution, the numerical difference between values with substantially different frequency may be small. For example, for precipitation, the difference between the .02 quantile and the .10 quantile for Cluster 20 (Ohio) in the month of July is only about 20% of the median precipitation for the month (Atlas).

Questions of Interest. In drought hydrology, it isn't always obvious what questions need to be answered. Some would say that what is ultimately desired is a) the frequency analysis of streamflow for some duration and b) procedures for estimating future streamflow from estimates of future precipitation. These are some, but not all, of the relevant questions.

Water managers are often required to answer questions posed by members of the lay public, such as government officials, industrial and business managers, members of environmental groups, the press, etc. Their questions are often expressed in probability terms, such as:

- what is the likelihood that we will get enough precipitation to be out of this drought next month or in the next two months? Or,

- what is the likelihood that streamflow will remain below normal over the next 6 months? Or,

- if we have another month of below normal precipitation, what will happen to streamflow?

Only the second of these three questions can even potentially be answered by an examination of streamflow statistics alone. The others, and many like it, ultimately can only be addressed by considering multiple parameters. The first and third questions are among the more likely questions to be posed by the lay public and are grounded in the common-sense notion that precipitation is the driving force behind streamflow. In fact, the probability of occurrence of streamflow deriving from a once-in-fifty year low precipitation will almost certainly not have the same probability of occurrence. This is because the streamflow probability is the result of factors other than precipitation, which have different probabilities of occurrence.

H - ALTERNATIVE DISPUTE RESOLUTION

COOPERATIVE ◄────────────────► **ADVERSARIAL**

UNASSISTED PROCEDURES	THIRD PARTY ASSISTANCE	THIRD PARTY DECISION MAKING	NONVIOLENT COERCION	VIOLENT CONFLICT
Informed Discussion	Conciliation	Administrative Hearing	Civil Disobedience	Terrorism
Negotiation	Facilitation	Binding Arbitration		Revolution
	Mediation	Litigation		War
	Mini Trial			
	Non-binding Arbitration			
	Settlement Judge			
Partnering	Dispute Review Board			

FIGURE H-1. THE ADR CONTINUUM

Alternative dispute resolution (ADR) is the name given to interventions in the decision making process which use a variety of methods developed in legal, labor relations, and other fields.

The original context of ADR was as an alternative to litigation. This annex includes a brief introduction to ADR methods and their applicability within the context of water planning and management, especially regarding droughts.

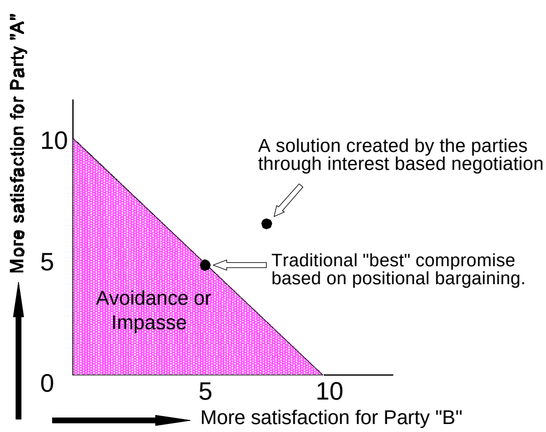
ADR Methods

The ADR continuum (Figure H-1) has been used for some time to display the range of methods for resolving disputes arranged according to the level of hostility. This version of the continuum is taken from a new Corps of Engineers handbook (Creighton, 1993). The preferred method is one that is more likely to produce better outcomes at a lower transaction cost. While lawsuits are considered the most hostile resolution in American water management disputes, war or physical violence is the extreme dispute resolution technique.

In ADR, the term “stakeholder” describes those parties to a problem solving process who have the ability to affect the outcome of the solution or are impacted significantly by the outcomes of the process. DPS teams will generally prefer ADR options to the left and towards the top of the ADR continuum as shown in Figure H-1. Those options give stakeholders greater “ownership” of solutions (that is, the stakeholders assume greater control over products and process and hence minimize concern about manipulation by outside interests or factors). In addition, options to the left and top generally have lower transaction costs, measured in dollars, time and intensity of conflict.

Informed discussion refers to communication among parties involved in a potential conflict in which information is shared and perceptions are measured separate from any declared intent to reach a formal agreement on resolution of the issues. Informed discussion reduces pressure on the discussants, and may be helpful in avoiding problems.

FIGURE H-2 INTEREST BASED NEGOTIATION CAN PRODUCE AGREEMENT ON “WIN-WIN” ALTERNATIVES THAT MIGHT NOT BE IDENTIFIED IN POSITION BASED BARGAINING.



Interest based negotiation is a type of formal negotiation by parties who have the authority to make commitments for the organizations they represent. *Interest based* bargaining or negotiation is different from traditional *positional* bargaining.

Positional bargaining embodies a strategy in which a series of positions are presented to other parties in a dispute in an effort to reach agreement. The positions are developed independently by each party in the negotiation, based on their interests and their *perception* of the other party’s interests. The first (opening) position represents the maximum gains the proponent hopes for, and subsequent positions demand less from the opponent and result in fewer benefits for the proponent. Agreement is reached when the parties positions converge. In Figure H-2, this movement occurs along the diagonal defining the shaded area.

In interest based bargaining, the parties collaborate to meet each others needs and satisfy mutual interests. Interests of the parties are identified prior to the development of solutions, and solutions are developed and evaluated jointly to meet real, not perceived interests. The creativity of all parties can be brought to the development of alternatives. The solution drawn outside the shaded area in Figure H-2 depicts the advantage of interest based negotiation, which is the increased probability of agreeing on solutions in which each party does better than the best compromise.

Cooperative Decision Making. Virtually all group process can be helped by some kind of structure. Too often, negotiations which involve decision making or problem solving involving parties in disagreement are free-for-all’s, with everyone loudly stating their positions and no one listening to anyone else. If one party offers suggestions for ground rules and structured process, the negotiations might proceed with a better chance of success. The intervention takes place within the group itself, and does not require the assistance of a neutral third party who is not a stakeholder in the negotiations.

Conciliation. This is a very informal process, whereby a third party may come in to assist in "fact finding" or helping the disputants form the relationships necessary to "come to the table." Generally, however, the parties still conduct the negotiations and decision making themselves.

Facilitation. Facilitators are used to help make group processes more effective and efficient. The facilitator is neutral on the substance of the dispute, and assumes responsibility for a structured process that helps the group achieve agreement and resolution of the problem. Facilitators are skilled in providing a "safe" setting for the airing of differences, keeping the meeting on track, insuring equal time for all participants, instilling a sense of fairness in the process, offering optional processes and approaches, and moving parties toward consensus.

Mediation. The use of a neutral third-party mediator to assist parties in conflict may be used with as few as two parties or, like facilitation, in a group setting. Unlike the facilitator, the mediator has permission to caucus with stakeholders outside the group setting, shuttle back and forth among parties, and offer solutions or strategies for breaking deadlocks. Mediators are trained to move disputants past their "positions" to a discussion of the underlying "interests" that may provide common ground for joint gains for all stakeholders. Stakeholders in the mediation should be willing participants in the process, with a shared intent to reach agreement if possible.

Mini-trial. A structured settlement process during which authorized neutrals hear a case and deliver findings upon which the *parties* make a decision.

Partnering is a formal, but non-binding agreement among parties playing different, but interdependent roles in an undertaking. Its first use in the Corps of Engineers was in construction contracting. The Corps and its construction contractors recognize that the job is supposed to be done well and the contractor is supposed to make money, and they work together to make both happen. In general, partnering is an attempt by such interdependent groups to create a working relationship conducive to trust, understanding and the pursuit of mutually acceptable goals. Parties make agreements in principle to share risks and promote cooperation. Partnering agreements were used in the National Drought Study DPS's to formalize the relationships that the DPS had developed.

Third Party Decision Making. Unlike facilitation and mediation which uses third party intervention only to assist stakeholders in finding agreement, there are a range of third party intervention options which remove the power of decision making from the disputants and transfers this control to the third party interveners. Examples of these techniques are mandatory, non-binding arbitration and voluntary, binding arbitration. Arbitration is a quasi-judicial process involving a judgement on the facts of the dispute.

The DPS method and public involvement principles in general stress the importance of stakeholder "ownership" of the final agreement. For that reason, the processes up to and including mediation on the ADR continuum are most appropriate for application to drought contingency planning. Within this realm, the decision making resides with the stakeholder group, even though assistance may be offered by outside parties.

However, the reality of the world of stakeholders in drought planning is often one of a history of ritualized conflict and competition with water management agencies and among different agencies with overlapping jurisdiction. The use of third-party assistance in the form of either facilitation (when the parties are able to handle substantive issues without too much conflict), or mediation (when moving the process and the substance along are both required) is useful, and often essential to the resolution or management of stakeholder conflicts in drought contingency planning.

ADR, Litigation, and Planning

ADR versus litigation. Any party considering litigation should consider ADR after discussing both avenues with counsel. An Executive Order and the policies of many agencies (including the Corps of Engineers) encourage its use. Among the most important issues to consider when faced with a choice between litigation and ADR are:

- *Are there persons from each potential entity in the conflict who can participate in the ADR process and who have the authority to make commitments for that entity?*

- *Can the issue be resolved independently, without resolution of a larger, overarching dispute?*

- *Is resolution of the issue on the facts acceptable, without the establishment of a precedent that clarifies a point of law?*

- *Is there a mechanism available to enforce or implement a decision reached through ADR?*

- *Can the dispute be resolved without endangering the parties needs for confidentiality?*

If the answer to any of these questions is "no", disputants may prefer to litigate, or to take remedial action so that the answer can be "yes".

ADR and planning. Some elements of alternative dispute resolution (ADR) techniques are synonymous with good planning and evaluation, such as the development of clearly stated objectives, openness to alternatives, and the use of defensible, replicable evaluation procedures. But sometimes conflicts can prevent planning from taking place or being effective. Conflicts in a DPS can be over human relationships, political power, data, interests, values, and elements of the study structure itself (such as time, institutions, unequal control or geographic balance). ADR experts can help in a planning study if:

- decision makers or important stakeholders have not invested authority with the DPS process, that is, have not agreed to accept the outcomes from the DPS process.

- there are conflicts among study participants not related to the study issues.

- interpersonal working relationships and communications are ineffective.

- there is a rigid adherence to a specific rational-analytic framework that does not identify or address underlying needs.

In addition, ADR experts can work with planners when study conflicts are aggravated by human factors. For example, a team member used to gathering and analyzing data may try to make data gathering the whole of the study, and that person's technical prowess may divert team members from designing a study that will achieve the planning objectives. ADR experts can work with planners to find ways to define an appropriate scope for data gathering while preserving the commitment of the data analyst to the study process.

Perhaps as important as the body of research and case studies, ADR experts can bring to a DPS the human skills for which ADR professionals are noted. Just as the engineering profession is associated with pragmatism and mathematical proficiency, ADR professionals often have a special capacity (enhanced by education and training) for effective listening, direct expression, and insight into the ways personalities affect study processes.

Getting to the table

Good water resources planning and management practice demands collaborative decision making and the sharing of information among four primary stakeholder groups: water users, water managers, advocacy groups, and others with special interests not included in the first three groups. If an important stakeholder boycotts the planning process, the process will not be effective. Hence, the most important ADR contribution to a drought study process may be getting stakeholders groups "to the table." A stakeholder that has dominant legal rights to water use, or that has the staff and funding to control water management information may believe that negotiation can only *reduce* their standing, and may refuse to be involved in a DPS, or worse, *pretend* to be committed to the process. This is a demonstration of rational self interest, no different in kind than a refusal to accept a "heads you lose, tails you lose" gamble. The impasse can only be broken if it can be demonstrated that there is a potential for the reluctant participant to gain from participation.

Referring to the diagram shown in Figure H-2, there are two general types of situations in which a stakeholder group can *mistakenly* assume that negotiating offers no opportunity for improving its position:

1. *When the stakeholder considers only the outcomes offered by positional bargaining* (solutions within the shaded triangle). In drought, positional bargaining is often tied to the quantity of water a stakeholder will receive when water is in short supply. However, bargainers should consider why the water is needed and how a refusal to participate in a DPS will affect the reluctant participant in areas not directly related to the DPS. For example, if the reluctant stakeholder uses water to make profit, the stakeholder could be given an opportunity to sell water at a profit in a water market. Indirectly related issues include the possibility of negotiation among the same groups on non-water issues, or a reduction in water management costs.

2. *When the stakeholder overlooks the possibility that its current advantage could be taken from it* (Figure 2 could be redrawn by a third party over the objections of the stakeholder, creating a "compromise" at a lower degree of satisfaction for the stakeholder). That was one of the most important lessons learned in the recent California drought (see the annex on that study beginning on page L-1): droughts can rearrange what was thought to be a stable balance of power in a regional water setting. Although many western water experts believed that appropriation law and water contracts guaranteed farmers a certain allocation of water during drought, they failed to consider the public pressure to change *collective choice* allocation rules if those rules do not seem to serve the public.

It may be true that the reluctant stakeholder has correctly assessed the situation or cannot be persuaded to disbelieve its incorrect assessment. DPS teams confronted with the refusal of an important stakeholder to participate should consider ending the study or decreasing its scope to preclude the need for involvement of the reluctant participant. To continue when there is no indication that the stakeholder will participate may be a waste of time and money, and may sour other participants on the concept of collaborative planning. A joint and public decision by other stakeholders to end a DPS may persuade the "pretend" participant to truly engage in the study process.

ADR and the Shared Vision Model

Shared vision models are a first attempt at creating a collective consciousness, where abstractions are all included, remembered in every evaluation, and are on display for every one to examine. A shared vision model can generally be as expert in each abstraction as each person can make it, and it insists on including each abstraction in every evaluation it produces. Hence, all are assured that they are important and that their knowledge and concerns are connected to decisions.

A shared vision model is not just a combination of hardware and software; not just new tool for manipulating data in creative ways. A shared vision model is also a PROCESS for dispute resolution. It can entice stakeholders to the table, but it also enhances the opportunity for moving through the stages of dispute resolution to a durable and implementable agreement. If the shared vision modeling process is used in combination with facilitation in a workshop setting, such as in a "Virtual Drought", the results can be exceptionally powerful in forging consensus on drought contingency plans.

The first agreement in the dispute resolution process is reached when people come together and have a look. The second stage of dispute resolution is what is often called "building a shared intent" to solve the problem. This is not as easy as it sounds. People can assemble for a problem solving exercise and then withhold or distort information, resist communication and negotiation, and mistrust others in the group. The role of the workshop facilitator at this point is to prod the participants, probing the reasons for resistance and lack of trust, working through past history and issues of turf, status and competition.

The role of a shared vision model as a dispute resolution partner, and one of the keys to its power as a public consultation and negotiation tool, is its ability to assimilate and display the expert knowledge each stakeholder adds during the model building process. In the DPS's, a three stage model building process was used to build trust in the model. First, each stakeholder group was interviewed, and portions of the model were built that pertained to the outputs and values of interest to them. These interviews also gave them an opportunity to see other parts of the model. Second, a joint workshop was held, and a series of exercises was used to determine if the model replicated behavior of the *system* well and understandably. Finally, the model was used in evaluating alternatives and virtual droughts, which allowed another opportunity for challenge and refinement. In the virtual drought held in Seattle, six challenges were made to the model's verity, but in each case, discussions within the group showed that the challenger was wrong, the model right.

Data conflicts are at the heart of the kinds of processes that are often stymied by an inability to agree on water management plans. The ability of stakeholders in a planning process to enter, display and manipulate data as a team, provides a powerful incentive to move forward in problem solving. To the extent that knowledge is power, allowing stakeholders to access system models directly can re-balance water policy dialogue.

And the problem of “who has expert status?” is also quickly solved, because all stakeholders sitting in teams at the computer have equal status as “expert” generators, repositories and manipulators of shared information.

Once participants in the DPS process come to the table and agree on a common goal to enter the process and move toward solutions, the work of negotiation begins. At this stage, the workshop facilitator assists stakeholders in defining problems and laying out issues, as they work together at computer terminals, playing “what if...” games and exploring scenarios. As mentioned above, workshop participants are all working from the same data base (what the dispute resolution professionals call “single text negotiations”), generating, refining, testing out, and narrowing the issues.

The workshop facilitator will begin to move participants in the negotiations toward a hard look at the basic interests and values which underlie the stated issues. Many of these interests are “non-negotiable”, for example retention of present infrastructure for water management (reservoir), even when an issue may have arisen suggesting the benefit of a change in infrastructure. But the shared vision model anchors the possibility of finding common ground. Options are generated more quickly, and the evaluation of those options takes place almost instantaneously with the shared vision model.

The time it takes to reach agreement is shortened, and the agreements are likely to be more durable.

In summary, attempts at inclusive and creative public involvement in public issues like how to respond appropriately to drought conditions, even using the art and science of dispute resolution, often fail because of the absence of methods to deal with the technical problems inherent in decisions involving large, competing data sets. But the application of dispute resolution techniques, such as facilitated problem solving workshops, in combination with computer-assisted decision making (using a tool such as STELLA II®), shows great promise for resolving long-standing disputes over the preparation and management of drought.

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I - DROUGHT AND THE PUBLIC

The public will be involved in droughts, and should be involved in drought preparedness efforts. The interactions with the public during planning and during droughts are different enough that different names have been applied to each, and different offices within water agencies assigned to each function. The phrase *public involvement* has generally been used to refer to efforts at including the public in planning, whereas *public relations* is more often used to describe the methods an organization uses to promote a favorable image with the public. *Public affairs* is somewhere in the middle, but it is the public affairs staff that will be (or should be) in charge of communication of information to the public during a drought.

Many water managers believe they practice good "public involvement" because they conduct regular meetings at which agency policies are explained and questions from the public answered. But this approach may not be effective in developing support for agency decisions or inducing changes in water users behavior that can reduce drought impacts. Water managers can compare their programs to the historical development of public involvement that follows. The annex concludes with a summary of conclusions from two studies concerning public information campaigns during droughts.

Public Involvement

Requirements for public involvement in water resources decision making have generally become more important within recent years. This situation presents problems to the planner, because there is no clearly defined established methodology, and there are limits to which public involvement can be extended without losing the technical effectiveness of the planning process. In the conduct of Drought Preparedness Studies, public involvement is necessarily an integral part of the basic process, as well as being required by legislation and policy designed for general application.

History of Public Involvement

The following brief history of public involvement is a summary from Hanna Cortner's essay on public involvement in <u>Governance and Water Management During Drought</u> (NDS-14).

By examining legal developments and case studies of participation programs in water resources, four eras can be identified: the era of closed participation; the era of maximum feasible participation; the era of environmentalism; and the era of collaborative decision building.

- *The Era of Closed Participation.* Water politics during this era was a closed system of decision making, controlled by local water users, federal water development agencies, and the authorizing committees in Congress, whose patterns of relationships were marked by clearly identifiable rules. Often described as "iron triangles", the policy outputs of this system were often said to be overbuilt, expensive, environmentally damaging and unnecessary water projects (Reisner, 1986; Maass, 1951; Ferejohn 1974; Morgan 1971). Participation, as well as analysis, served the political purpose of rationalizing projects (Ingram 1972; Lord 1979). Participation was marked by one-way communication flow; its purpose was largely educational and informational, designed to sell plans and gain local support (Daneke 1977). The public was viewed as clients who had a mutual interest in pursuing water development.

- *The Era of Maximum Feasible Participation.* After World War II two significant policy trends would converge and profoundly affect water policy: (1) the growth of legislation and policies designed to protect the environment; and (2) an increase in legal requirements and programs designed to broaden the participation of the public in governmental decision making. Some of the earliest programs that made specific attempts to broaden the participation of affected and interested public's occurred in the area of social welfare policy. Soon the expectations and demands for public participation carried over to other policy areas. A 1965 presidential order directed all federal agencies to improve their communication with the public (Langton 1993). In the area of water, the Water Resources Planning Act of 1965, for example, required that "water related initiatives be conducted on a comprehensive and coordinated basis by the federal government, state, localities, and private enterprise with the cooperation of all affected federal agencies, states, local governments, individuals, corporations, business enterprises, and others concerned." In response to the growing public demand for public access to decision making and amidst growing environmental controversies, the Corps of Engineers began to implement methods of informing and involving a greater range of interests. The goal of participation still remained largely educational and informational and relied heavily on formal, e.g., public hearing, techniques (Daneke 1977).

- *The Era of Environmentalism.* The 1970's saw an explosion of environmental legislation, as well as mandates for public involvement. The public became increasingly concerned about the environmental impacts of pollution, but also about the preservation of land and water resources. These public concerns were also coupled with an increasing distrust of experts, and a growing skepticism over the validity of technological decisions (Desario and Langton 1987).

The decade began with the signing of National Environmental Policy Act (NEPA) of 1969, which declared a national environmental policy for the nation, and greatly expanded the public's right to have environmental impacts disclosed and to participate in the disclosure process. NEPA requires agencies contemplating actions that will significantly affect the environment to prepare environmental impact statements. It also specifies that those statements will be assembled by interdisciplinary teams, consider non-commodity as well as commodity values, and afford the public an opportunity for review and comment.

Despite the considerable investment of time, dollars, and personnel that participation efforts received during the 1970's and 1980's, controversies persisted and sometimes even escalated. Many conflicts over resource management issues continued to land in court. Attempts to devise ways to resolve conflicts without resorting to litigation spawned the development of alternative dispute resolution techniques, including for example: negotiation, mediation, arbitration, and partnering (provides for a joint planning approach between agencies failing to reach agreement by normal means. Partnering was adopted as a policy by the Chief of Engineers in March 1993.) However, such procedures still would fall far short of a full collaborative approach.

- *The Era of Collaborative Decision Building*. There have been approximately three decades of experimentation with public participation methods and techniques (Creighton et al. 1983; Advisory Commission

on Intergovernmental Relations 1979). Based on numerous evaluations of past public involvement efforts, a set of performance criteria has emerged.
Generally, effective public involvement has the following characteristics:

- two-way communication;
- involvement early and through the entire process;
- deliberation involving informal and personal processes; and
- representation of all interests (Blahna and Yonts-Shepard 1989)

Despite all of our experiences in public involvement, meeting these standards has been an elusive goal. They will remain challenges for the future.

Forms of Public Involvement

There are many different forms of public involvement, all geared toward the interrelated goals of changing government behavior or changing citizen behavior. Most successful methods seem to involve a series of informal contacts between groups, two-way communication, and shared decision making. The difficulty comes in sharing decision making. If agency officials (or other leaders) really do not intend to let their decisions be influenced by outsiders, and if the other interests are unwilling to compromise with opinions of the agency, no amount of skilled public involvement techniques will provide an agreed solution. However, with care, better results can be achieved, by using working groups of diverse membership, oriented initially towards the problems, and, on occasion, by open public meetings and surveys of citizens' attitudes and opinions. Procedures of Alternative Dispute Resolution may be applied as appropriate (see Appendix H).

Public participation may help to:

- increase administrative accountability;
- to supply pertinent information;
- to evaluate methodological approaches and use priorities;
- to raise broad but related value questions;
- to call planners' attentions to immediate problems;
- and to make plans more politically acceptable.

More generally, it has been stated that public involvement represents the move from representative democracy to participatory democracy, with the responsible officials conveners and facilitators rather than managers. However, such theories should not be taken too far. Public involvement is a remedial technique, designed to correct abuses, and increase the credibility of decisions, but leaving intact the basic responsibility of officials. There is clearly no unified theory of public involvement which would satisfy everybody. Approaches employed must be appropriate to the specific situation and be perceived as fair by the principal participants, but can vary widely.

There are considerable differences of opinion regarding the extent to which the general public should be involved in planning rather than dealing only with representatives of identified key interests. The persons involved, in addition to legally constituted decision makers, must include "stake holders" whose interests are affected, even though legally they have no power of decision.

Special Characteristics of the DPS

The Drought Preparedness Study is not a traditional project planning study, but, as brought out in the main report, is a cooperative undertaking between responsible federal and non-federal agencies. Cooperation between the Corps and other decision makers is not only a matter of policy, but is an essential part of the structure of the Study. The completion of the study is in the form of an agreement. Usually the participating agencies include federal agencies, one or more states, and large municipalities. Therefore public involvement for a DPS inherently includes collaboration and agreement with specified decision makers. It also includes a more general responsibility to the general public, in accordance with laws, policies and directives applicable to water resources planning generally.

Public involvement, mandated or encouraged by numerous laws and directives, is not a clearly specified process or technique, but one dependent upon particular circumstances. An open cooperative approach is desirable, but it should be one that recognizes the basic responsibilities of officials, and the importance of a well-focused planning process.

Public involvement features two-way communication, use of informal contacts and work groups, more citizen participation, more sensitivity to environmental impacts, and a chairman functioning as a facilitator (as well as a manager).

In DPS, collaboration is two-fold. The Corps works collaboratively with other key agencies in formulating the agreements which together form the framework of the plan. However, the Corps also works cooperatively with other stakeholders and the general public in implementing laws and policies applicable to public involvement in water resources planning in general. In preparing for a DPS, careful attention must be given to both aspects of the public involvement process.

Public Affairs

During a drought, the effectiveness of drought responses is often a function of the trust, knowledge, and commitment of the public. Two examinations of how agencies and the public communicated during California droughts highlight the issues that water managers should consider in developing the part of their tactical plan that deals with public information.

Analysts drew three conclusions about the media from the recent California drought (NDS-5):

- **The role of the media is not well understood by water managers.** The media are governed by their own rules of objective reporting, newsworthiness, and perceptions of what the public wants to know. They cannot be managed by water agencies. If they were, they would not be able to sell news. The questions like, “Are we in a drought?” or “Is the drought over?” are not silly questions from the media’s point of view. Reporters understand the thinking modes and perceptions of the general public much better than water professionals. For them, once the water supply situation is called a drought, it automatically implies that behavior has to be changed from normal behavior to crisis behavior. Such a change is newsworthy.

- **The media cannot improve on imprecise and ambiguous messages.** Most likely, the statements will become even more confusing after they are reported in the press. Only unambiguous and complete answers to questions that are asked by the press can be communicated clearly to the public.

- **Media cannot explain complex water management issues.** What is very interesting to water professionals is usually “too dry” for newspapers, radio, and television. Long feature articles on water issues do not sell newspapers, but timely, well-written articles during a drought emergency will be read by concerned people.

<u>Consumer Response to the Drought Media Campaign in Southern California</u> reports the results of surveys to evaluate the effects of the Metropolitan Water Districts large scale media campaign to inform the public about the drought and to recommend water saving measures. Here are some of the key findings from the study:

1. There was a statistically significant increase in the public’s awareness of the drought after the campaign, and those who became aware of the drought through the campaign were more likely to believe in the seriousness of the drought and to conserve water. Television appeared to be the most effective medium for increasing awareness.

2. Even after the campaign, water users greatly underestimated the amount of water they used, but the error was less than before the campaign.

3. The people most willing to reduce water use were also the most likely to report they needed more information on how to do so.

4. The campaign increased trust that the agencies call for conservation was necessary and should be supported.

5. Support for farmers use of water was greater after the campaign, while support for commercial and industrial use declined. It is generally accepted in social behavior research that conservation campaigns will be more effective if the sacrifices are fairly shared. This suggests that publicizing the equity of drought restrictions may be effective in reducing water use.

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J - CONCEPTUAL BASIS FOR CIRCLES OF INFLUENCE

From the outset, accomplishing the National Study of Water Management during Drought involved confronting an organizational dilemma: how can planning be timely, technically sophisticated, cost effective and also inclusive of the hundreds of thousands and even millions of people impacted by a drought?

The organizational concept dubbed "Circles of Influence" was used during the National Drought Study and is recommended for use in other water resources studies. The concept is explained in Chapter 3 of this report. This annex describes the origins of the concept.

The planning dilemma

The principal objective of a Drought Preparedness Study (DPS) is to effect changes in a regional water management that reduce the impacts of drought. Because such changes most often take the form of behavior modifications, the changes will be more effective if the impacted community is engaged in the solution to drought problems.

Drought conditions themselves, however, complicate the realization of this community commitment. The drought community - the mass of people who share the impact of drought conditions - typically overlaps or outruns established jurisdictional boundaries. Drought conditions, in addition, intensify the multiple short-run competing interests of different community segments. The work of developing a drought plan, in contrast to this competitive perspective, involves taking a long-term perspective, accepting cost and benefit tradeoffs among interests, and risking free-rider exploitation.

Concepts behind circles

The circles of influence concept can be summarized in terms of two basic assumptions. First, in attempting to bring together in a common ongoing effort the many varied and more or less organized segments of a community, many different modes of participation have to be utilized. Second, building links among these different modes of participation typically requires the creation of new community institutions.

Five key elements define the circles of influence concept.

- First, a cadre with the appropriate mix of skills, time, and the necessary influence/utility in the broader community is needed to spearhead community change.

- Second, everyone in the community affected by a target problem has to have their fingerprints on a viable solution. Varied levels and types of participation are needed to accomplish this inclusive involvement.

- Third, the development of the circles of influence has to be opportunistic, i.e., it is necessary to exploit the salient problems and resources on the table at a given point in time.
- Fourth, communication among the circles is necessary to build a sense of a cause everyone is working on, has a stake in, and is going to get credit or blame for.

- Fifth, a criterion for the effectiveness of the circles of influence is their efficiency in producing the decisions needed to advance the implementation of plans.

These key elements of the circles of influence concept underlie the two basic working assumptions stated above. Assumption one (many different modes of participation have to be utilized) emphasizes the need to build an organization on the base of the varied capacities and constraints of community members required for a solution. These varied capacities and constraints can include time, skills, interests, other commitments, and community positions.

Assumption two (building links among these different modes of participation typically requires the creation of new community institutions) emphasizes the need in organizing, to move beyond ad hoc contacts to new patterns of working together. It is necessary to leave something behind which endures because the community has experienced its value.

These assumptions suggest a basic hypothesis: breaking community patterns and creating new patterns occurs when community members realize through their actions and experience of other people's actions that they are part of something that makes gut sense, that works, and that is generally recognized as successful.

This circles of influence theory did not evolve out of study and research but rather out of practical experience of Dr. Robert Waldman, an organizational expert who developed the concept for the DPS's. In the late 1960's, Dr. Waldman worked as a community organizer in a west Baltimore neighborhood troubled by housing speculation, crime, and a lack of public services, including police who did not respond to calls. In trying to work out a way to deal with this situation, he got ideas from three sources: Alinski community organizers who were in Baltimore at the time, a friend who was involved with Steelworkers Union organizers, and his brother who was at Da Nang in psychological operations and had left him material on Viet Cong organization strategies.

It struck Dr. Waldman that, for all the fundamental differences among these movements and even their inconsistent awareness of each other, many of their basic concepts were similar. The circles of influence theory is based on these similarities.

Although based on the intuition of practiced organizers, the advantages of Circles of Influence can be related to some of the fundamental ideas influencing current social science research. The work of four individuals, in particular, grounded these research traditions.

Morton Deutsch initiated, in the 1950's, the main tradition of social psychological conflict resolution research. This tradition has focused on the identification of the conditions under which participants will evolve a cooperative or a competitive relationship in a situation which permits either. The findings of this tradition support the idea that successful experience with cooperation leads to the development of more general and long-range cooperative orientations.

Mansur Olson, an economist, initiated in the 1940's a tradition of interdisciplinary social science research on the conditions of collective action. The key idea in this tradition is that the mass of people make the commitments required to effect social or structural change primarily on the basis of their awareness of the individual benefits and costs associated with their commitments. The findings of this tradition support the need for inclusive involvement in the process to develop a personal stake in movement outcomes.

Charles Tilley, a historical sociologist, initiated in the 1960's a tradition of research using secondary data on the historical development and impact of social movements. The key idea in this research is that social structural change is a function of the interaction of long-term historical trends and purposeful efforts to affect the course of change. The findings of this tradition support the importance of the opportunistic exploitation of the circumstances at a point in time to move beyond planning to actual change.

Finally, Richard Emerson, a sociologist, initiated in the 1970's a tradition which integrated ideas from behaviorist psychology, market economics, and the anthropology of nonindustrial cultures.

A key insight of this tradition is a broadening of the concept of exchange beyond supply-demand or benefit-cost transactions to include commitments to an exchange system in spite of transactions which might be unfavorable to an individual at a point in time. In the context of a DPS, the commitment to an exchange system would mean cooperation with a long-term drought strategy in spite of uneven immediate benefits and costs. The commitment would still occur because of a stake in the strategy itself and the belief that rules for distributing costs and benefits over time are fair.

The origins of the concept are offered as more than an intellectual exercise. The underlying concepts discussed above can be turned into questions managers can use to assess the degree of support they have achieved from the DPS team:

- *do team members rate early, short term experiences such as the first workshop as successful? (experience with cooperation leading to committed cooperation)*

- *do team members have and perceive a personal stake in the process?*

- *do they understand that the DPS may be a unique opportunity to address these problems collaboratively and that it must be exploited?*

- *do team members see both long term, widespread benefits and the short term risks and costs of participating in a collaborative study?*

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K - FORECASTING WATER USE TO MANAGE WATER CONSERVATION

Sophisticated water use forecasting methods are now commonly used to size future water supply projects, and are being used more often as the basis for measuring the potential savings from long term conservation measures. Algorithms have been available to estimate the savings from combinations of curtailment measures that reduce water use just during droughts. Although this use is far less common, the latest version of the most widely known water forecasting model should make the practice much more common.

The purpose of this annex is to present the importance of water use forecasting methods in designing drought curtailment plans and determining the relationship between long term conservation measures and the potential to secure additional demand management savings during drought. In addition, this annex provides a brief explanation of disaggregated water use forecasting.

History. Simple per capita projections of future water use were used to size city water supply systems until the 1960's, when concerns about water supply limitations and the environmental impacts of structural water projects stimulated the development of disaggregated water use forecasts. "Disaggregated" forecasts identify component variables such as climate, price and household size that can be related mathematically to water use; water use forecasts are then based on projections of those variables.

A classic study of residential water use was conducted at Johns Hopkins University from 1961 to 1966 to determine the water use patterns and demand rates imposed on water systems in residential areas and to define the major factors influencing residential water use (Howe and Linaweaver 1967). A number of subsequent studies have used information from this early research project. The project was sponsored by the Federal Housing Administration in cooperation with 16 participating utilities from throughout the United States. Master-meter, punched tape recorder systems were installed to continuously monitor water flow into 39 homogeneous residential areas served by the 16 water utilities. The 39 study areas ranged in size from 34 dwelling units to 2,373 dwelling units.

During the late 1970's and early 1980's, the Institute for Water Resources (IWR) of the U.S. Army Corps of Engineers conducted research to develop methods for evaluating municipal and industrial water conservation plans, including improving water use forecasting capabilities. Probably the best known product of this body of research is the series of computerized water use forecasting models called IWR-MAIN (**I**nstitute for **W**ater **R**esources **M**unicipal **A**nd **I**ndustrial **N**eeds). A recently developed computer program called IWRAPS correlates water use on military bases with the area of dozens of facility types such as hospitals, bachelor housing, and administration.

IWR-MAIN has been used in many fast growing cities in the western United States, including the metropolitan areas of Southern California, Las Vegas and Phoenix. Disaggregated forecasts not incorporating IWR-MAIN have been done in other cities, such as Seattle, and still others cities have used hybrid systems, usually spreadsheet models with some, but not all of IWR-MAIN's equations.

Applications in long term planning. Disaggregated forecasts allow more reliable forecasts of unconstrained water use, that is water use that would take place if there were no limit on supply. But disaggregation can also help planners estimate the effectiveness of water conservation programs. The newest version of IWR-MAIN, in beta testing as this report goes to press, includes two separate and independent water use forecasting strategies. The first is more similar to earlier versions of MAIN, although the indicator variables have been changed (for example household income is now used instead of housing prices). The second forecast approach is based on estimates of twenty end uses, such as toilets, urinals, showers, and evaporative coolers. Each end use itself has several component factors that affect how much water will be used in that type of fixture throughout the study area. This "ultimate" disaggregation offers the greatest promise for evaluating the effects of specific conservation programs, such as rebates to retrofit toilets that use less than 2 gallons of water per flush.

Applications in drought curtailment planning. Disaggregated water use forecasting methods can also aid in designing drought curtailment programs. For example, sprinkling bans are among the most commonly used curtailment measures; a city that has developed long term water forecasts using the use categories of IWR-MAIN would have calibrated estimates of outdoor water use for each of several classes of residential single and multi-family homes. The calibration of disaggregated forecasts requires the close examination and allows the careful accounting of water use by category, including water lost to leaks. The more reliable the estimate of outdoor water use, the better the estimate of the savings provided by sprinkling bans. These estimates are not just important for assuring that competing uses can be met; they can also be used to adjust water prices to assure that utility revenue can cover expenses during the drought.

Application in balancing long term water conservation and the "cushion" of curtailment during a drought. Water managers have often expressed the concern that long term conservation eliminates the "fat" that can be cut into when cutbacks are necessary to survive a drought. William Elliott, of the Water Supply Citizens Advisory Committee in Massachusetts, debunks the notion that *conservation* is the villain by pointing out that if it were good to have "fat" to cut into, the best preparation for drought would be to leave faucets running all the time. Mathematically it is clear that, to the extent that water saved in conservation programs can be stored, it can even reduce the frequency and impacts of urban water shortages.

But although water conservation can reduce water and energy costs, one of its primary purposes is to spread available supplies among more customers. In fact, it is often touted as the least cost method of meeting the water needs of an expanding population. When long term conservation is used in lieu of additional supplies, there is a *potential* for reducing the effectiveness of curtailment measures. For example, as a city converted from turf to xeriscaping *and used that water inside the homes of new residents*, sprinkling bans would lose their effectiveness as curtailment measures. On the other hand, water saved from leak detection programs, even if used to supply new customers, would not affect short term curtailment plans, since water savings from leak detection and repair takes much more time to realize than saving from banning lawn watering.

Water Use Forecasting Methods

Water use forecasting can be characterized by (1) the level of complexity of the mathematical relationships between water use and explanatory variables or determinants of water use, and (2) the level of sectoral, spatial, seasonal, and other disaggregation of water users. *Disaggregation* refers to making separate estimates for categories and subcategories of water use. For example, sectoral disaggregation involves separate water use predictions for residential, commercial, industrial, institutional, and public uses which, in turn, can each be divided into numerous subcategories. The separate water use forecasts are aggregated or added together to obtain the total water use.

In the simplest disaggregated forecasts, water use per customer coefficients are estimated for each customer class. Thus, water use forecasts can reflect varied growth rates among the customers. Commercial and industrial water use is commonly forecast on a per employee basis. Disaggregated forecasts for specific sectoral categories are frequently expressed as a single coefficient function of other variables, such as number of hotel rooms or hospital beds.

Water use forecasting models are often based on regression equations which relate mean or peak water use rates to one or more determinants of water use (explanatory variables). A typical general form of the regression equations is as follows:

$$Q = \alpha + \beta X_1^a + \gamma X_2^b + \ ... + +\xi X_n^m$$

where:

Q = forecasted water use rate
X = explanatory variables
n = number of explanatory variables
α - ξ = regression coefficients or parameters

Typical examples of explanatory variables include: resident and seasonal population; personal income; number, market value, and types of housing units; employment; manufacturing output; water and wastewater prices and rate structures; irrigated acreage; climate (arid or humid); weather conditions; and water conservation programs. A disaggregated forecast may involve any number of equations representing various categories and subcategories of water use. Up to a point, greater forecast accuracy and greater flexibility in representing alternative future scenarios and management strategies can be achieved by increased disaggregation and inclusion of more explanatory variables in the forecast equations. The exact form of each forecast equation and value for the coefficients can be determined from regression analyses of past water use data for the particular study area. Alternatively, generic equations have been developed based on data from many study areas representative of geographic regions or the entire nation. Water use forecasting methods are sometimes differentiated as being either requirements models or demand models. Requirements models do not include the price of water, or other economic factors as explanatory variables, thus implying that water use is an absolute requirement unaffected by economic choice. Demand models include the price of water to the user as an explanatory variable, as well as related economic variables such as income.

The water use forecasting methods noted above are based on projections of future values for the determinants of water use. Data is also required to develop the coefficients in the regression equations. Thus, data availability is a key consideration in water use forecasting. Data are available from a variety of sources. For example, historical data and future projections related to population, personal income, housing, and employment can be obtained from published census data and

OBERS regional projections, local and state planning agencies, econometric firms, and state and national statistical abstracts. Climate data is available from National Weather Service publications as well as from various federal, state, and local agencies. Water use data for the study area and information regarding local water and wastewater pricing and water conservation programs are obtained from water utilities and local agencies.

IWR-MAIN

The IWR-MAIN Water Use Forecasting System is a software package which provides a variety of forecasting models, socioeconomic parameter generating procedures, and data management capabilities.

IWR-MAIN was originally based on the MAIN model developed by Hittman Associates, Inc., in the late 1960's for the U.S. Office of Water Resources Research, which was in turn based on earlier work by Howe and Linaweaver (1967) and others. In the early 1980's, the Institute for Water Resources (IWR) adopted and modified MAIN and renamed the revised model IWR-MAIN. During the 1980's, IWR-MAIN evolved through several versions representing major modifications. Version 5.1 has recently been replaced by Version 6.0. The model is available by contacting IWR or Planning and Management Consultants, Ltd. (PMCL). PMCL periodically offers a training course on application of IWR-MAIN, in coordination with IWR and the American Public Works Association.

IWR-MAIN is a flexible municipal and industrial water use forecasting system. Forecasts are made for average daily water use, winter daily water use, summer daily water use, and maximum-day summer water use. IWR-MAIN provides capabilities for highly disaggregated forecasts. Water requirements are estimated separately for the residential, commercial/institutional, industrial, and public/unaccounted sectors. Within these major sectors, water use estimates are further disaggregated into categories such as metered and sewered residences, commercial establishments, and three-digit SIC manufacturing categories. A maximum of 284 categories can be accommodated, but most forecasts utilize approximately 130 specific categories of water use.

Water use is estimated as a function of one or more explanatory variables such as number of users, number of employees in nonresidential categories, price of water and sewer service, climate and weather conditions, and conservation programs.

Preparation of an IWR-MAIN water use forecast requires: (1) verification of the empirical equations and coefficients for estimating water use and (2) projection of future values of determinants of water use. Model verification is accomplished by preparing independent estimates of water use for one or more historical years and comparing these estimates with *actual* water use conditions. If necessary, the model can be calibrated. The base year is the year from which values of explanatory variables are projected. A calendar year that coincides with the U.S. Census of Population and Housing is typically selected as the base year. One or more subsequent years are selected as the forecast years for which water use is predicted.

Comparing IWR-MAIN Version 5.1 and Version 6.0

IWR-MAIN 6.0 and the previous version, 5.1, are both disaggregated forecasting models, but differ in several significant ways:

- Both versions forecast residential use by correlating it to several variables such as price and housing density. There is one important change in the set of variables: Version 6.0 forecasts based on household income, whereas 5.1 uses housing values. A comparative study in the Metropolitan Water District of Southern California showed that a forecast based on household income is *less* likely to be skewed by regional housing locational premiums.

- Version 6.0 has a supplemental forecasting system by “end-use” categories (faucets, toilets, washing machines, etc.) that can be used to estimate the effectiveness of water conservation measures. Version 6.0 is able to use these forecasts to estimate the benefit/cost ratio for various conservation strategies.

- Version 6.0 uses more standardized demographic information than Version 5.1, and it is easier to input.

- Version 6.0 divides residential use into different categories from Version 5.1. The advantage of the change is that there are Census data to support the percentages of residences in each category Version 6.0 uses. In 5.1, the number of residences in each category could be estimated only after considerable research.

- Version 6.0 can forecast non-residential water use based on major industry groups and 2 or 3 digit **S**tandard **I**ndustrial **C**ode (SIC) employment forecasts. This allows forecasters to make the forecast more or less disaggregated, depending on the need to do so versus the costs and availability of data. (A note of explanation: SIC’s create a nested classification of commercial, industrial, and public water users. For example, all construction activities have a code that starts with a “1”; “15” is for general building contractors, and “152” is for residential building construction. These SIC designations are used for a wide variety of statistical purposes, and forecasts of employment in each are made by the U.S. Census.)

- Version 5.1 and 6.0 create and manipulate data bases in the process of developing forecasts, but Version 6.0 has greater database management handling capability.

- Version 6.0 embodies the current state of knowledge of water use behavior in residential and non-residential sectors. All versions of MAIN include default coefficients that correlate water use with many explanatory variables. These default coefficients are based on studies of the relationship between water use and the selected parameters. Version 6.0 benefits from many new studies across the country that have been published since Version 5.1 was inaugurated.

- Version 6.0 uses a “friendlier” user interface.

These changes mean that 6.0 will produce better forecasts with less work. Perhaps more importantly, the new IWR-MAIN is much more helpful in determining the effectiveness of long term conservation measures.

TABLE K-I. WATER CONSERVATION REPORTS FROM THE IWR CONSERVATION PROGRAM

Changing Water Use in Selected Manufacturing Industries	October 1974
The Role of Conservation in Water Supply Planning	April 1979
An Annotated Bibliography on Water Conservation	April 1979
The Evaluation of Water Conservation for Municipal and Industrial Water Supply, Procedures Manual	April 1980
Selected Works in Water Supply, Water Conservation and Water Quality Planning	May 1981
An Annotated Bibliography on Techniques of Forecasting Demand for Water	May 1981
An Assessment of Municipal and Industrial Water Use Forecasting Approaches	May 1981
The Evaluation of Water Conservation for Municipal and Industrial Water Supply, Illustrative Examples (Volume II)	February 1981
Analytical Bibliography for Water Supply and Conservation Techniques	January 1982
The State of the States in Water Supply/Conservation Planning and Management Programs	January 1983
Forecasting Municipal and Industrial Water Use - IWR Main System	July 1983
User's Guide for Interactive Processing and User's Manual	
Forecasting Municipal and Industrial Water Use: A Handbook of Methods	July 1983
Influence of Price and Rate Structures on Municipal and Industrial Water Use	June 1984
Handbook of Methods for the Evaluation of Water Conservation for Municipal and Industrial Water Supply	October 1985
IWR-Main Water Use Forecasting System Version 5.1	June 1988
Water Use Forecasts for the Boston Area Using IWR-MAIN 6.0	August 1994

L - LESSONS LEARNED FROM THE CALIFORNIA DROUGHT 1987-1992

One of the most valuable sources of information about how to prepare for drought is the experiences of those who have survived a severe drought. The full value of these experiences, though, can be realized only if the lessons are recorded, critically analyzed, and communicated to others who can use the information. That was the objective of the National Drought Study analysis of the California drought. This "Lessons Learned" study captured the views of some 100 key members of the California water community, representing 57 organizations. The participating organizations included federal, state, regional, and local water supply agencies as well as environmental, private, and governmental entities that control and influence water management in the state.

The approach used to identify the important lessons of the drought consisted of three activities:

- Literature review of published and unpublished documents
- Field interviews, and
- Critical review of the draft findings by survey participants and other water professionals.

The lessons are shown in Table L-I. Lessons learned in previous droughts and confirmed in the 1987-92 drought are displayed in Table L-II.

TABLE L-I. LESSONS FROM THE 1987-1992 DROUGHT

- The complexity of impacts of a sustained drought demands more sophisticated planning.
- Severe drought can change longstanding relationships and balances of power in the competition for water.
- Irrigation can provide complementary environmental benefits.
- Drought can force water supply solutions on a community that they would not have otherwise accepted.
- The success of drought response plans should be measured in terms of the minimization and equitable redistribution of the impacts (as opposed to shortages), but there is much to be learned about the best ways of accomplishing this goal.
- Severe droughts can expose inadequacies in the existing roles and performance of state and federal water institutions, causing significant institutional and legal changes.
- Increases in water rates should precede or accompany rationing plans.
- Mass media can play a positive role in drought response, but only if water managers help design the message.
- Market forces are an effective way of reallocating restricted water supplies.

FIGURE L-1. TRENDS IN CALIFORNIA WATER USE

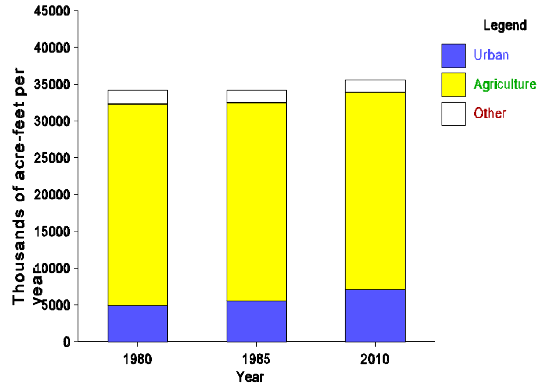


TABLE L-II. LESSONS FROM PREVIOUS DROUGHTS CONFIRMED IN THE 1987-1992 DROUGHT

- Groundwater continues to be the most effective strategic weapon against drought.
- The surest way to mitigate the adverse social, environmental, and economic impacts of a sustained drought is to ensure that more water is made available through a variety of management measures.
- Early drought response actions and proper timing of tactical measures are essential in the short-term management of droughts
- Local and regional interconnections among water supply systems proved to be a good insurance policy against severe water shortages.

Background. While the statistics on per capita freshwater withdrawals do not distinguish California from other states, the statistics on consumptive net water use in California are noteworthy. The state accounts for almost 22 percent of total consumptive use in the nation, nearly twice its share of population (Solley 1993). This situation can be attributed to intensive agricultural and manufacturing activities throughout the state.

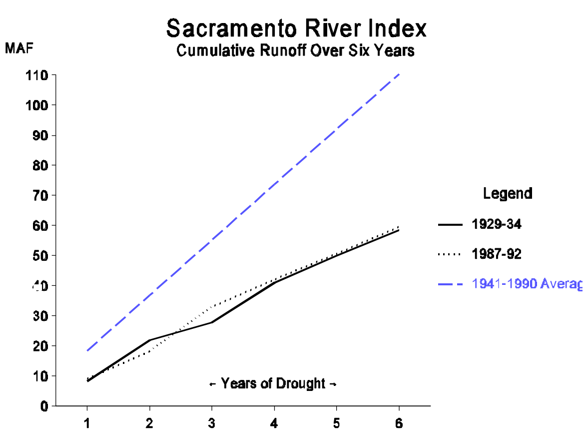
A major portion of the state is served by two primary suppliers who operate an extensive system of storage reservoirs and aqueducts: the State Water Project (SWP) and the Central Valley Project (CVP). The distribution system reaches 75 percent of the state's population (CDWR 1987). Both projects export water from the Sacramento-San Joaquin Delta, which has become the focal point of a number of water related issues.

Groundwater supplies about one-third of the water for urban and agricultural use in California in an average year. During a year of average precipitation and runoff, an estimated 14 million acre feet (MAF) of groundwater is extracted and applied for agricultural, municipal, and industrial use. The average annual net groundwater use (total extracted minus recharge from applied water) for the state is 8.5 MAF. This rate of groundwater extraction exceeds the average recharge by about 1 MAF, but it represents a reduction from earlier years when extraction exceeded recharge by 2 MAF. Groundwater use varies from 20 to 90 percent of applied water withdrawn, depending on the region.

California's $20 billion dollar agricultural sector (CDWR 1990) uses much more water than other sectors, although in recent years the percentage has declined. In 1980, net agricultural water use was 80.1 percent of total net water use. By 1985, that had declined to 78.8 percent. California's projected population growth is expected to result in an increase in net urban water use between 1985 and 2010 (Figure L-1). This increase will take place largely in the state's coastal regions, where 80 percent of California's current population is concentrated. The urban percentage of total net water use is also expected to increase during that period by about four percent.

SEVERITY OF THE 1987-1992

FIGURE L-2. TWO SIX YEAR CALIFORNIA DROUGHTS OF THE 20TH CENTURY



DROUGHT

The 1987-1992 Drought was not "the big one". The National Drought Atlas (NDS-4) does not estimate probabilities of droughts longer than 5 years in duration, so an estimate of the rarity of this 6 year drought cannot be made directly. However, according to the Atlas, no five year precipitation total (i.e., 1987-1991 or 1988-1992) in any of California's ten hydrologic regions was more rare than a fifty year drought. By at least one important measure (the Sacramento River Index) this drought was very similar to another six year drought that occurred from 1929 to 1934 (Figure L-2). Finally, as Figures L-3 through 6 show, no individual year from 1987 to 1992 was nearly as severe as the 1977 water year. In short, although this was a severe drought, planners should expect one as bad or worse in the next century.

DROUGHT RESPONSES

FIGURE L-3. PRECIPITATION 1987-1992

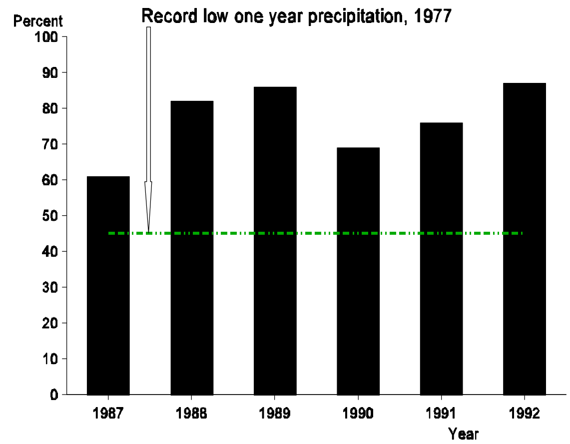


FIGURE L-4. 1987-1992 RESERVOIR STORAGE

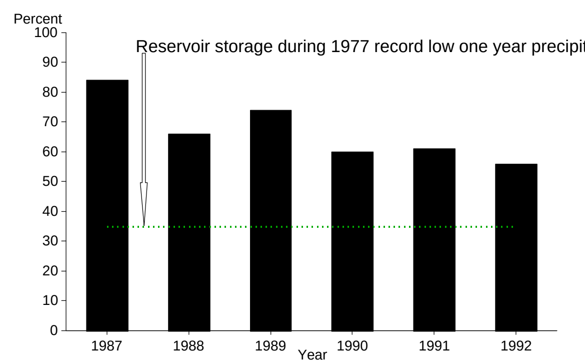
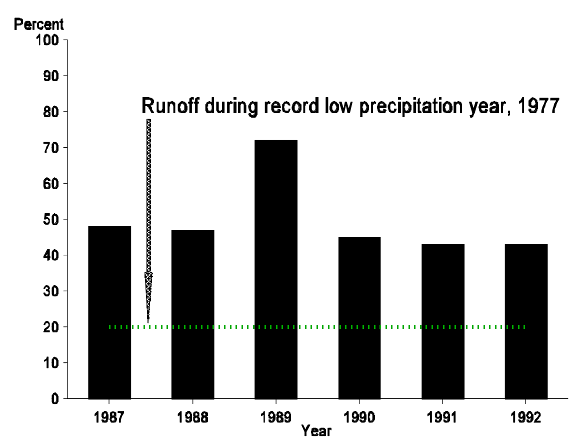


FIGURE L-5. 1987-1992 WATER YEAR RUNOFF



Water Allocation and Deliveries

Those entitled to water from the SWP and CVP did not suffer any significant reductions in deliveries until 1990. These two major projects supply water for agricultural and municipal water uses, with the SWP accounting for 7.4 percent and the CVP providing 21.7 percent of California's supplies during the first three years of the drought. However in 1990, drawdown in project reservoirs prompted the first major cutbacks in CVP and SWP deliveries. The drought conditions intensified in 1991, necessitating even more drastic reductions in water deliveries.

Urban Water Conservation

Figures L-7 to L-9 display how Oakland, Los Angeles, and San Diego reduced water use during the drought. The East Bay Municipal Utility District (EBMUD) which supplies water to urban customers in the Oakland area, initiated conservation measures in 1988. Los Angeles and San Diego started to conserve in 1990. Across the state, demand management efforts consisted of both voluntary and mandatory conservation programs during the first three years of the drought, with target reductions in water use ranging from 10 to 25 percent.

A survey of local governments in Southern California conducted by the Los Angeles Times (April 1990), indicated that there were voluntary conservation programs in 45 communities, whereas conservation was mandated in only 17 communities. As the drought progressed into the fifth year (1991), the "Miracle March" rains and the success of the Water Bank (below) helped most communities cope with water shortages. The results of a survey conducted in May 1991 showed water use reduction goals among the 11 members of the California Urban Water

FIGURE L-6. EAST BAY MUD WATER USE 1982-91 (EBMUD, 1994).

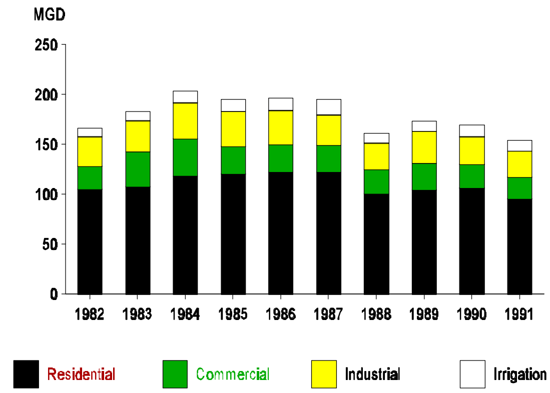


FIGURE L-7. WATER USE AND POPULATION GROWTH FOR THE CITY OF LOS ANGELES (LADWP, 1994).

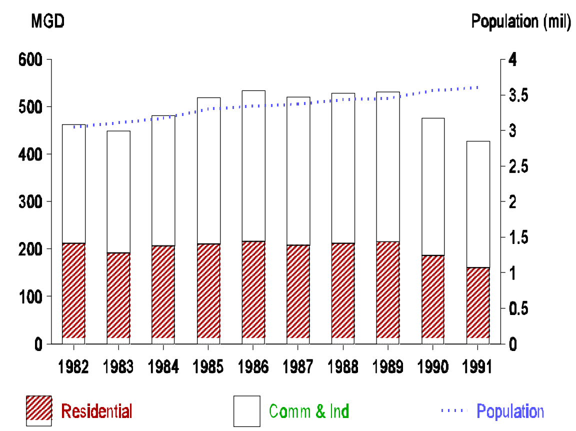
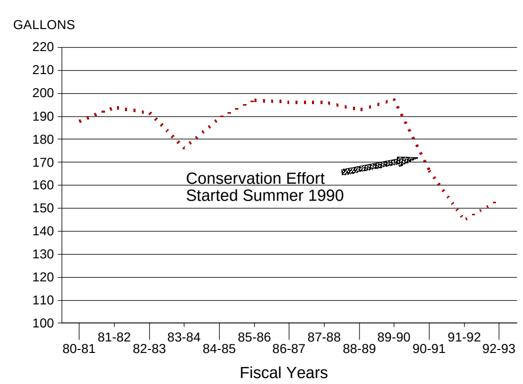


FIGURE L-8. SAN DIEGO PER CAPITA CONSUMPTION, WATER YEAR ENDING JUNE 30 (CITY OF SAN DIEGO. 1992).



Agencies (CUWA) varied from a low of 10 percent for the Los Angeles Department of Water and Power, to a high of 31 percent for MWD.

One important development at the end of the fifth year (September 1991) was the signing of the **Best Management Practices** (BMP's), statewide agreement monitored by the California Urban Water Council. The conservation program pursued by the water agencies in the sixth year (1992) included some of the 16 BMP's advocated in the Memorandum of Understanding agreement. Components of this program included educational publications, technical workshops, business conferences, training courses, water use surveys, water management studies, and a telephone hotline.

Groundwater Withdrawals

California's groundwater basins provided a reliable source of water during the 1987-1992 drought, similar to its role during previous droughts. Increased extraction in combination with other factors such as reduced recharge resulted in decreased groundwater storage during the drought. The change in groundwater storage during the drought for three different regions of the Central valley is shown in Figure L-9. These regions are important because they are the largest agricultural producers in California, and represent 65% of the average net groundwater used in the state (CDWR 1993).

The State Drought Emergency Water Bank of 1991

The fifth year of drought (1991) brought greater water shortages (following the first significant SWP and CVP cutbacks in the fourth year of drought), and on February 1, 1991, the Governor signed Executive Order

FIGURE L-9. CUMULATIVE CHANGE IN GROUNDWATER STORAGE FROM 1970-1992

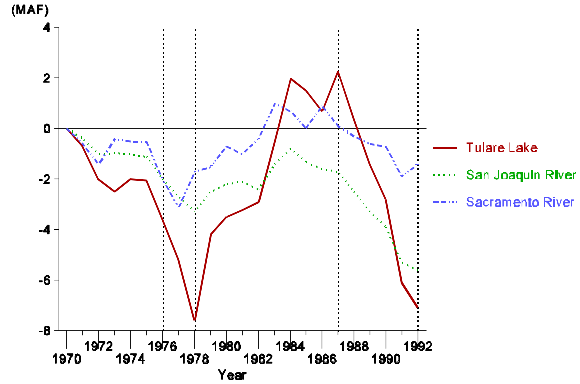
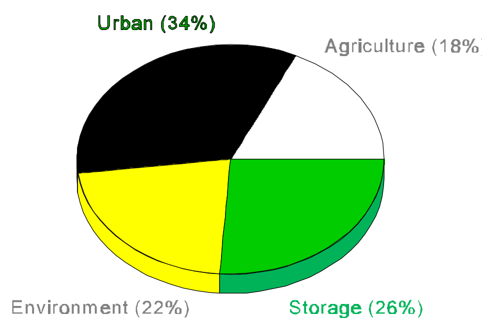


FIGURE L-10. WATER BANK ALLOCATIONS: 1991-1992 (CDWR 1993)



No. W-3-91 that established the Drought Action Team. The executive order established a State Drought Emergency Water Bank. The Bank provided water for environmental, urban, and agricultural use (Figure L-10). The establishment of the Emergency Water Bank was a major innovation. It created a voluntary market for the transfer of water on an economic basis. The Emergency Water Bank would not have been possible without the CVP-SWP conveyance facilities.

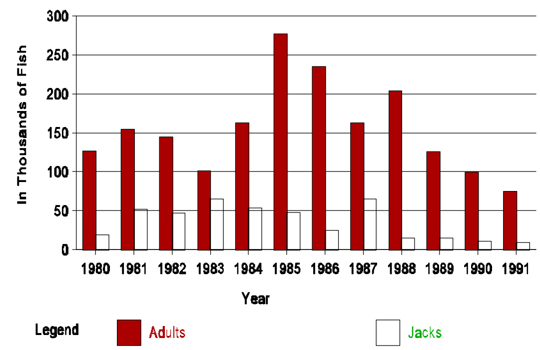
Other Responses

Discussions among representatives from the agricultural, urban, and environmental groups referred to as the "Three-Way Process" began before the drought, but received considerable media attention as the drought intensified. The process did not produce tangible products during the drought; in fact, it became bogged down by the conflicting agendas of the various interest groups, just as it has for decades. However, respondents in this study felt that the process improved working relationships between competing interest groups, forming relationships which continue today.

IMPACTS

Impacts from the long drought were felt to some degree in many water use sectors. According to many observers, including the California Department of Water Resources (1991b), probably the most severe impacts of the drought were suffered by fisheries and aquatic resources, particularly species such as salmon. The population of the fall-run chinook salmon declined to its lowest numbers in the last two decades (Figure L-11) despite consistent hatchery production. How much of this population decline might be attributed to drought is not known, since the population decline might also have been affected by record catches of salmon off the nearby Pacific Coast. Agriculture did not suffer substantial impacts until 1991, the fifth year of the drought, when revenue declined slightly from a record of $18.3 billion in 1990. Direct agricultural revenue losses during the drought were about $250 million (CDWR, 1992). The loss in consumer and producer surplus, a truer measure of the impact to society, was $276.3 million in California, but only $80 million nationally because of the increases in farm production elsewhere in the country. The only industry that was significantly affected by the drought was the "Green Industry" (Cowdin and Rich 1994, in prep), including landscaping and gardening. Drought-induced economic losses in 1991 were estimated to include the loss of about 5,630 full-time jobs, and about

FIGURE L-11. NATURAL FALL-RUN CHINOOK SPAWNING SALMON (1980-91)



$460 million in gross revenue, a 7% decline from 1990. The lack of impacts in other industrial and commercial industries has been attributed to a number of factors, including exemptions for some industries from mandatory water allocation rules, implementation of new water conservation practices, and in a few cases, substitution of groundwater for surface water. The drought reduced hydroelectric power generation. Hydroelectric plants typically provide 33-40% of the total electrical energy produced in California. From 1987 through 1990, that percentage was never more than 20%. The drought cost state ratepayers about $3 billion (increase in marginal cost) as a result of lost energy production. Utilities replaced this power by natural gas and out-of-state power purchases (CDWR 1991b). Table L-III summarizes some of the economic loss estimates.

Given the sustained turmoil and press coverage surrounding the California drought, it is surprising to see how small the economic impacts of the drought were. And in the sector with the largest economic impacts by far, hydropower, there was little controversy. Somewhere therein lies perhaps the most

Table L-II. Estimates of Economic Impacts

Sector	Duration	Loss ($)	Sector Revenue in 1990	Study
Agriculture	1991	$276 million	$18 billion	NDS-10
Hydropower	1987-1992	$3.8 billion	$62 billion	U.S.E.L.A. 1993

fundamental lesson for drought planners elsewhere in the country: that the degree of conflict is not necessarily a function of the likely value of impacts. The uncertainty that is intellectually recognized by water managers is felt more personally by those who “hold stake” in the allocation of scarce water, even by those who advocate a philosophy of use. It suggests that reductions in drought conflicts are more likely to come from the reduction of anxiety among stakeholders than the absolute reduction of the expected value of impacts. That in turn argues for involvement of stakeholders in the planning process, because that allows them to understand the risks and prepare for them personally while there is still time to do so.

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M - A Summary of the Principal National Drought Study Case Studies

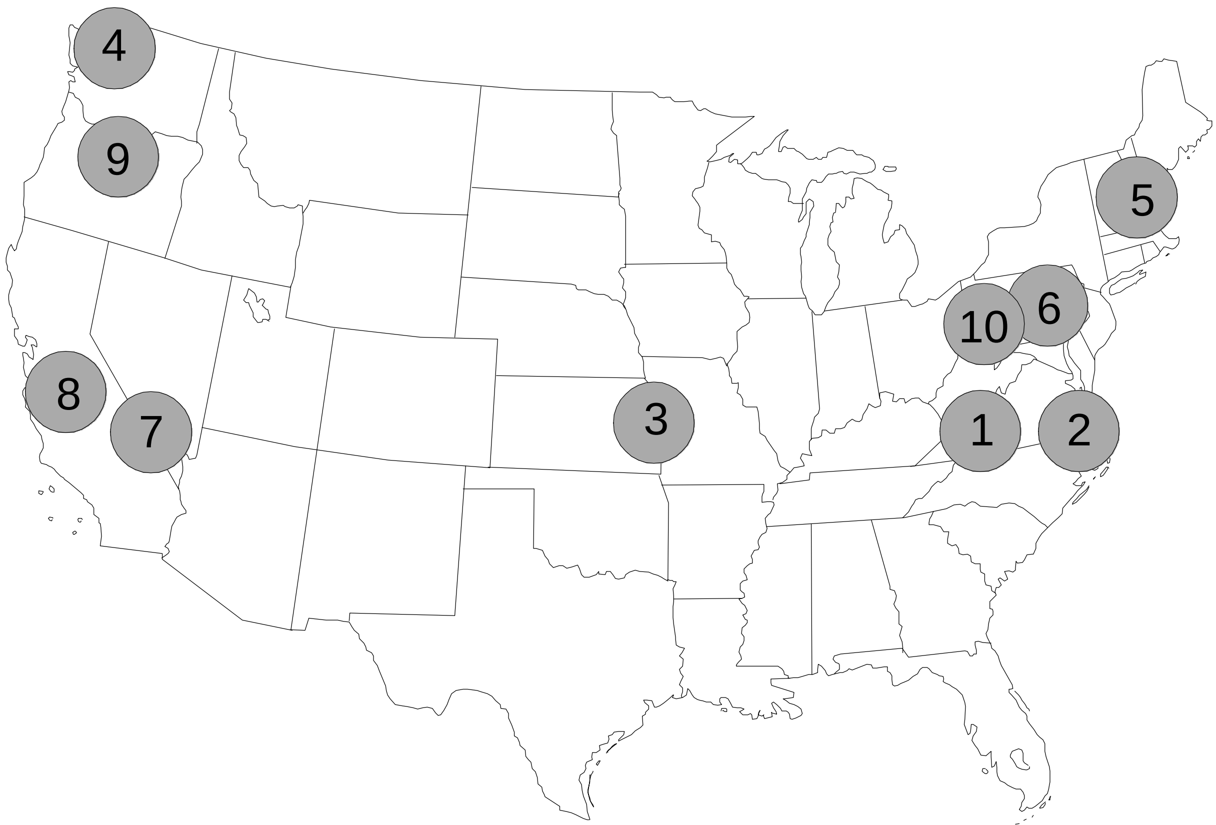

Figure M-1. *Case Studies Conducted During the National Drought Study*

Four river basins were chosen to test and refine the "DPS Method" of managing water during drought. In addition, smaller studies were conducted in the Boston and Harrisburg areas. The National Drought Study collaborated with a team of western universities on a gaming exercise in which the Colorado River States experienced a severe (computer simulated) drought. The DPS method is now being tested at two Corps lakes (9 and 10) to determine its effectiveness as a method to develop reservoir drought contingency plans under limited budgets and time.

1. Kanawha River DPS (WV, NC, VA)
2. James River DPS (VA)
3. Marais des Cygnes-Osage Rivers DPS (KA-MO)
4. Cedar-Green Rivers DPS (WA)
5. The Boston Area (MA)
6. Susquehanna River Basin (PA)
7. Colorado River (7 states)
8. California (Lessons Learned, Impacts from the Drought)
9. Rogue River, Lost Creek Lake (OR)
10. Youghiogheny River Lake (PA)

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The planning methods described in this report were first published in 1991 (NDS-1) and have since been tested and refined in four Drought Preparedness Studies (DPS's) across the United States. The study sites were chosen from 28 nominated sites to represent a cross section of issues in American water management. To supplement that experience, smaller studies that focused on specific issues were conducted in Boston and the Susquehanna River Basin. Finally, many of these methods were used in a collaboration between the National Drought Study and the "Study of Severe Sustained Drought in the Southeastern United States", a comprehensive analysis of what would happen in the Colorado basin and California if an extreme drought were to occur in the near future.

Each of these studies lasted over two years. The DPS's will be described more fully in Lessons Learned from the National Drought Study Case Studies (NDS-15). Colorado River Gaming Exercise (NDS-14) describes that work in more detail. The summaries of these studies that follow describe the primary conflicts, the participants, and the changes that occurred, or are in the process of occurring. One DPS, the Marais des Cygnes-Osage, was suspended during the summer of 1993 because the entire "Circle A" of the study team became involved in the efforts to control and monitor the flooding damage on the Missouri and Mississippi Rivers. That DPS is expected to resume in March 1994 and conclude in the fall of 1994.

The Drought Preparedness Studies

1. The challenge for the **Kanawha River DPS** team was to strike a better balance between water quality, lake boating, and white water rafting below Lake Summersville on the Gauley River, a tributary to the Kanawha.

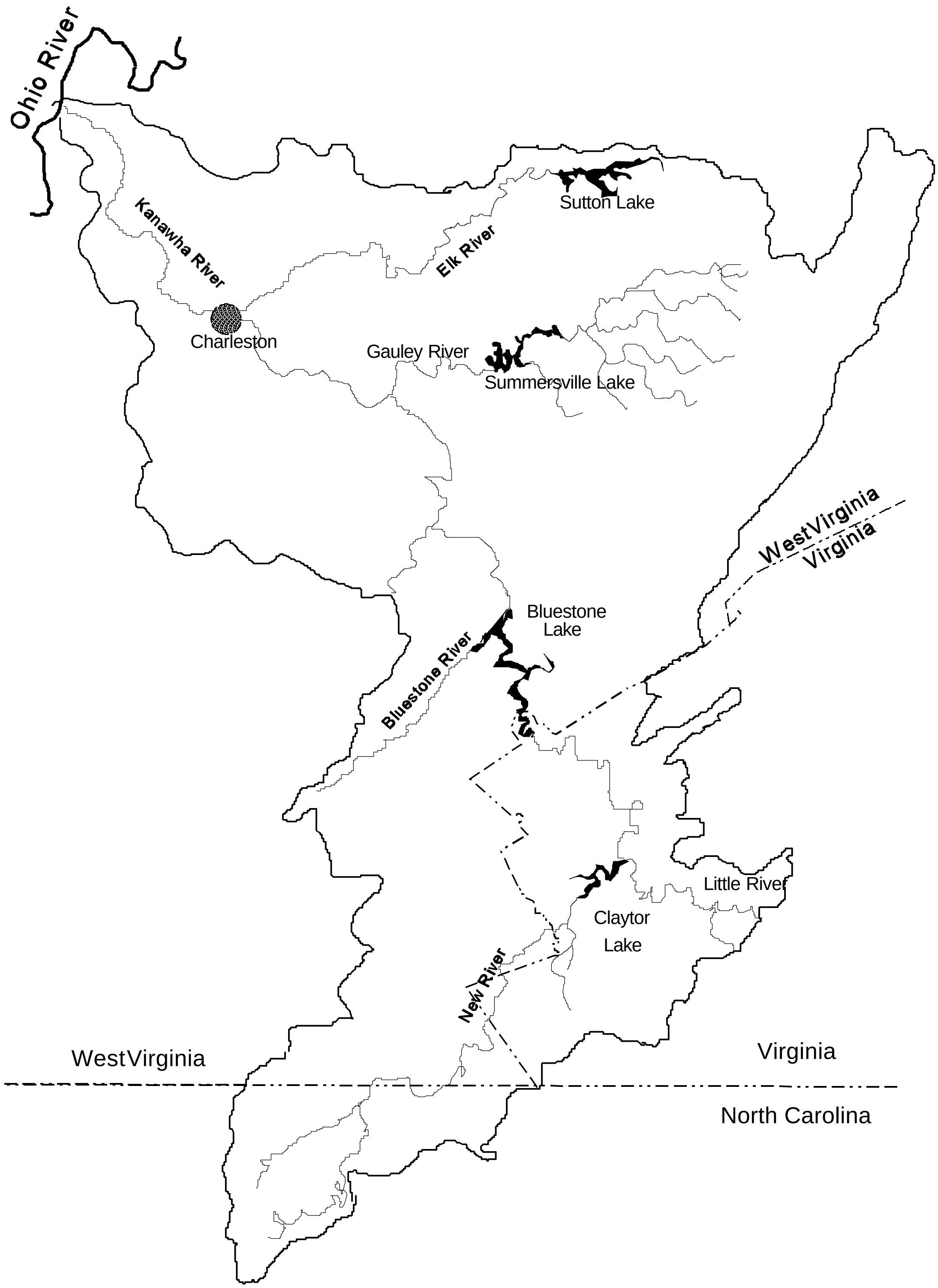
The Kanawha drains 12,300 square miles in North Carolina, Virginia and West Virginia. The Kanawha main stem is formed by the junction of the New and Gauley Rivers, and flows northwest 97 miles before emptying into the Ohio River at Point Pleasant, West Virginia. Other major tributaries are the Greenbriar and the Elk. The Corps is the primary water manager, operating locks and multi-purpose reservoirs at Lakes Summersville (Elk River), Bluestone and Sutton (on the New River). The Appalachian Power Company, which runs the hydropower plants on all three Corps reservoirs, also owns and operates Claytor Lake, on the upper New River. Claytor Lake also supports lake recreation.

The most recent drought started with below average rainfall in the summer of 1987, and persisted through the fall of 1988, with temperatures several degrees above normal in the summer of 1988. During that drought, releases from Summersville and Sutton were kept high enough through August to meet minimum instream flows established to dilute downstream effluents. By August, there was no longer enough water in the reservoir to support daily pulsed releases for whitewater rafting or meet minimum instream flow requirements. The restriction of rafting releases to just weekends cost the region millions in tourism revenue. For the tourists coming from all over the world, it created, for the first time, doubts about the dependability of the rafting experience. Releases from Corps reservoirs kept dissolved oxygen levels above 5 mg/l, the state minimum, until August 1988. Then, with the reservoirs running out of water, and temperatures at their highest, the levels of dissolved oxygen dropped, sometimes to less than 3.5 mg/l.

Circles A and B in the Kanawha included the Huntington District Corps of Engineers (planning and water control), the West Virginia Division of Water Resources, the U.S.

Geological Survey, the West Virginia Geological Survey, and representatives from the whitewater outfitters. Circle "C" included

FIGURE M-2. THE KANAWHA RIVER BASIN



natural and water resources departments from all three states, including departments of fisheries, the U.S. Fish and Wildlife Service, Trout Unlimited, the Isaak Walton League, regional councils of government, the National Weather Service, Offices of Emergency Service, the North Carolina Regional Council of Governments, the Kanawha Valley Chemical industry, and municipal water suppliers.

Changes as a result of this DPS. The study team first quickly looked at a broad range of tactical and strategic plans, up to and including the construction of additional reservoirs. Almost all but the tactical alternatives were eliminated early in the study process as improbable because of the amount of time necessary to develop solutions and because of environmental concerns. After the collaborative planning model was developed, the remaining alternatives were screened to see how well they addressed the planning objectives. Planners found that modifications to Claytor Lake, Bluestone, and Sutton did not significantly address the planning objectives. In a workshop in the spring of 1993, Circle B team members compared five alternatives for Summersville Lake to the status quo plan.

Plan 1 was to modify the dam at Summersville to allow the summer pool level to be 17 feet higher. **Plan 2** called for relaxation of water quality target flows. (A USGS survey showed that BOD loadings had been dramatically reduced since the standards were set). **Plan 3** was to ignore the rules that limited releases from Summersville in the fall (lower limiting rule curve) in order to maintain a preset minimum level of storage. **Plan 4** delayed the starting date for water quality releases from June 15 to July 15th unless water samples showed a need for the releases. **Plan 5** was to vary the maximum water quality release from Summersville, starting at 500 cfs (instead of 1000 cfs) and increasing through August (the month in 1988 when releases were cut to 400 cfs because of the lower limiting rule curve).

THE PLANNING OBJECTIVES FOR THE KANAWHA RIVER DPS

1. Increase the reliability and value of the Gauley River whitewater rafting experience during drought conditions.

2. Increase reliability of the recreational opportunities in-stream and on lakes in the Kanawha River basin during drought.

3. Increase the reliability of navigation on the Kanawha River during drought.

4. Increase the reliability of hydropower generation in the Kanawha River basin during drought.

Workshop participants watched as the shared vision model was run to demonstrate the impacts of each alternative during a one and two year drought. Measures of performance for each objective were compared. After three hours of model runs, Dr. Richard Punnett, head of the water control section of the Huntington District Corps of Engineers, led a workshop exercise designed to facilitate the transition from individual plan evaluations to the endorsement and implementation of a plan. This exercise is described in Chapter 8 of this report because of its general usefulness as a tool for clarifying the final decision making process.

The analysis showed that Plans 4 and 5 helped water quality, rafting, and lake recreation, while not affecting hydropower or navigation. Plan 2 helped rafters, but hurt lake recreation; Plan 3 did just the opposite. Because plans 4 and 5 were not mutually exclusive, the workshop participants agreed that a plan that combined the advantages of both should be used during the next drought.

In August 1993, the Huntington District used the shared vision model and the close collaborative ties it had developed with stakeholders to react to a potential drought. An alternative release strategy was agreed to by the DPS team consistent with the general form of alternatives 4 and 5. The drought watch was lifted after heavier than normal rainfall. Participants agreed that had the drought continued, these operational changes would have preserved fall water quality and avoided several million dollars loss in West Virginia tourist revenue derived from whitewater rafting.

2. **The James River DPS**. The primary objective of the James River DPS was to reduce urban drought vulnerability in a five city region near where the James flows into Chesapeake Bay. The cities, in order from most to least vulnerable, are Virginia Beach, Chesapeake, Suffolk, Norfolk and Portsmouth. They do not use James River water, but instead rely on a mixture of groundwater, local runoff, and withdrawals from the Nottoway and Blackwater Rivers. The James River DPS team developed a simulation model of the five city region using the STELLA II® software, and supported a new role for the state of Virginia.

The James River is located almost entirely in Virginia (less than 0.1 percent of the basin is in West Virginia). The James flows 340 miles southeast from the Allegheny Mountains on the West Virginia border to Chesapeake Bay. About a fourth of Virginia - 11,000 square miles - is in the James River basin. The major tributaries are the Maury, Rivanna, Appomattox, and Chickahominy Rivers. Workshops held throughout the basin showed that the worst drought problems were in the five-city area, although the Lower Peninsula area and greater Richmond area will probably have problems in the future. The problem is not an uncommon one in the U.S.; population growth is the greatest at the coast, where groundwater pumping can lead to saltwater intrusion.

Circle A of the James River DPS team was made up of staff from the Norfolk District, Corps of Engineers, Virginia Department of Environmental Quality, U.S. Advisory Commission on Intergovernmental Relations, Institute for Water Resources, the Virginia Water Resources Research Center (Virginia Polytechnical Institute and State University), the city of Virginia Beach, the Appomattox River Water Authority, and the University of Washington. The state has begun to use the DPS methods on other river basins. Early interest from environmental groups came mostly from the Isaac Walton League and the Lower James River Association. Circles "B" included about 50 organizations including municipal water utilities, environmental groups, other state and Federal agencies, industries and industrial groups, and Universities. Circle "C" included a mailing list of about 400 agencies and individuals.

1. Increase the reliability and level of municipal water service in the lower James basin during drought conditions.

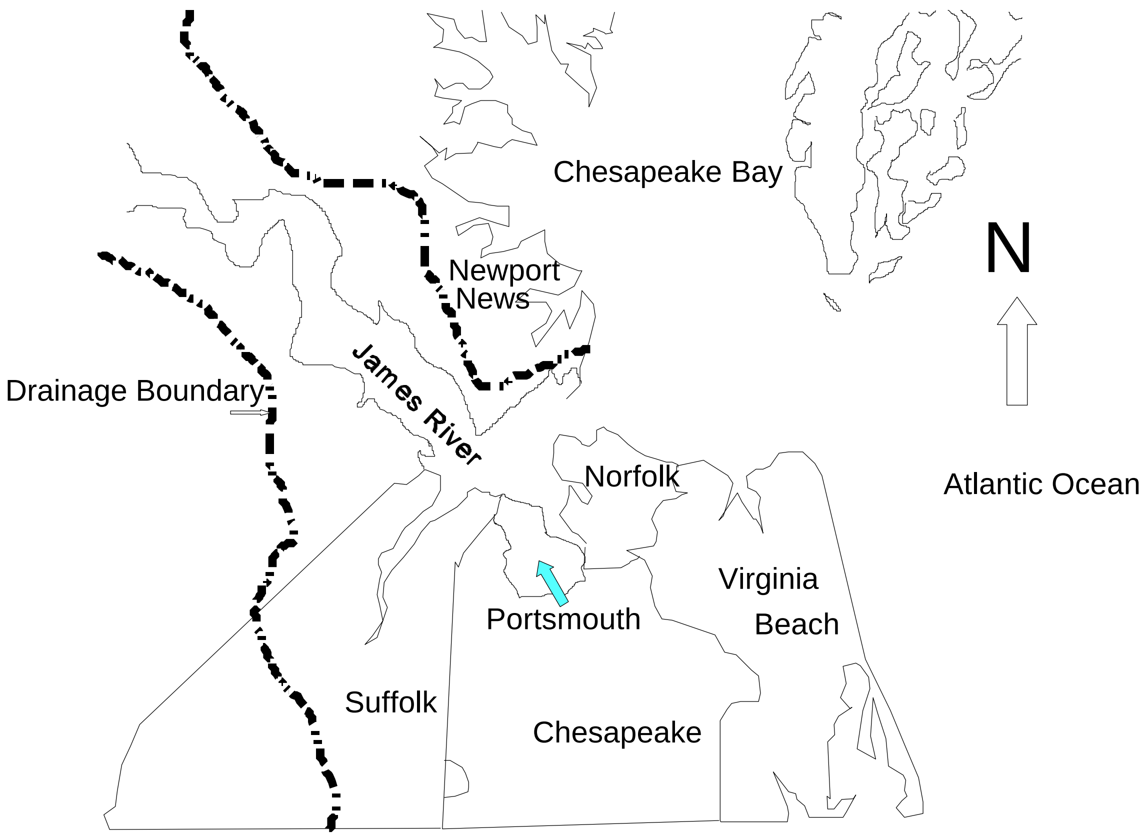
2. Increase the population of the nine indicator species along various reaches of the James River during severe droughts.

3. Increase water quality reliability in the James River basin during drought.

PLANNING OBJECTIVES - JAMES RIVER DPS

Of the five cities, Virginia Beach is the most vulnerable. Virginia Beach will have no water supply of its own until 1996, when the Gaston pipeline, now under construction, is scheduled to carry water from the Roanoke River east across Virginia. Until then, Virginia Beach will rely entirely on water from the city of Norfolk, which also supplies some water to the city of Chesapeake.

FIGURE M-3. DROUGHT PROBLEMS IN THE JAMES RIVER BASIN ARE CONCENTRATED IN A 5 CITY AREA.



A shortage situation during a non-drought period now exists in the city of Virginia Beach. In 1986, Virginia Beach initiated voluntary conservation, and in 1991, mandatory use restrictions were enforced. Then, in 1992, when Norfolk limited Virginia Beach's demand to 30 MGD, Virginia Beach instituted year-round mandatory water use restrictions and a limited construction moratorium. Conservation measures have long been implemented in Virginia Beach, resulting in the very low per capita water use rate of about 82 GPD.

But the amount of "surplus" water available to Norfolk during a severe drought may be less than 30 mgd. In a 1980-81 drought, Norfolk had to institute penalties for water users who consumed more than 75% of normal amounts. The U.S. Navy, a major economic force in this area, at one point owed more than $140,000 in fines. It is thought unlikely that Norfolk would restrict Navy water use before reducing the amount of water transferred to Virginia Beach. The potential impact to the local economy from additional base closures will intensify the pressure on Norfolk to assure reliable water service to the Navy.

Changes as a result of this DPS. In August of 1993, the five cities and the Corps participated in a workshop in which the shared vision model of the five city region was used to simulate what would happen if the drought of 1980-81 were to happen under today's water demand and allocation rules. Alternatives including regional management and conjunctive use of emergency wells were examined, but were rejected in favor of the status quo. As of the date of this report, although it appears unlikely that the DPS will effect a reduction is short term vulnerability, the five cities are considering using the shared vision model to manage droughts collaboratively in the region.

The potential for strategic changes is somewhat greater. The Virginia Water Commission, a group of state legislators and gubernatorial appointees, met on July 22, 1993 to consider ideas - including those of the James River DPS team - for a more proactive state water role. Testimony was offered by National Drought Study representatives, and the shared vision model was demonstrated. The Virginia Department of Environmental Quality made a presentation on components that should be included in a state water policy. At the end of the DPS, most observers believed that the state of Virginia would develop a comprehensive state water policy. The New Role for the Commonwealth of Virginia might include:

- providing technical and political analysis, or interpreting the needs and perspectives of various water management groups where communication among those groups is poor now.

- stronger protection of the state's interest in local and interstate water issues.

- integration of institutional perspectives across regulatory, supply planning, and use; across Federal and state responsibilities; and across legal, engineering, biological, and economic professional perspectives.

- dispute resolution, either as a facilitator or a regulator. In the regulatory role, the state could readjust power balances among water uses by new, or newly enforced regulation.

- dispute adjustment - using state law and regulation to support parties whose success in water negotiations would benefit the public.

- arrangement of technical assistance from outside the state.

- a written state water policy.

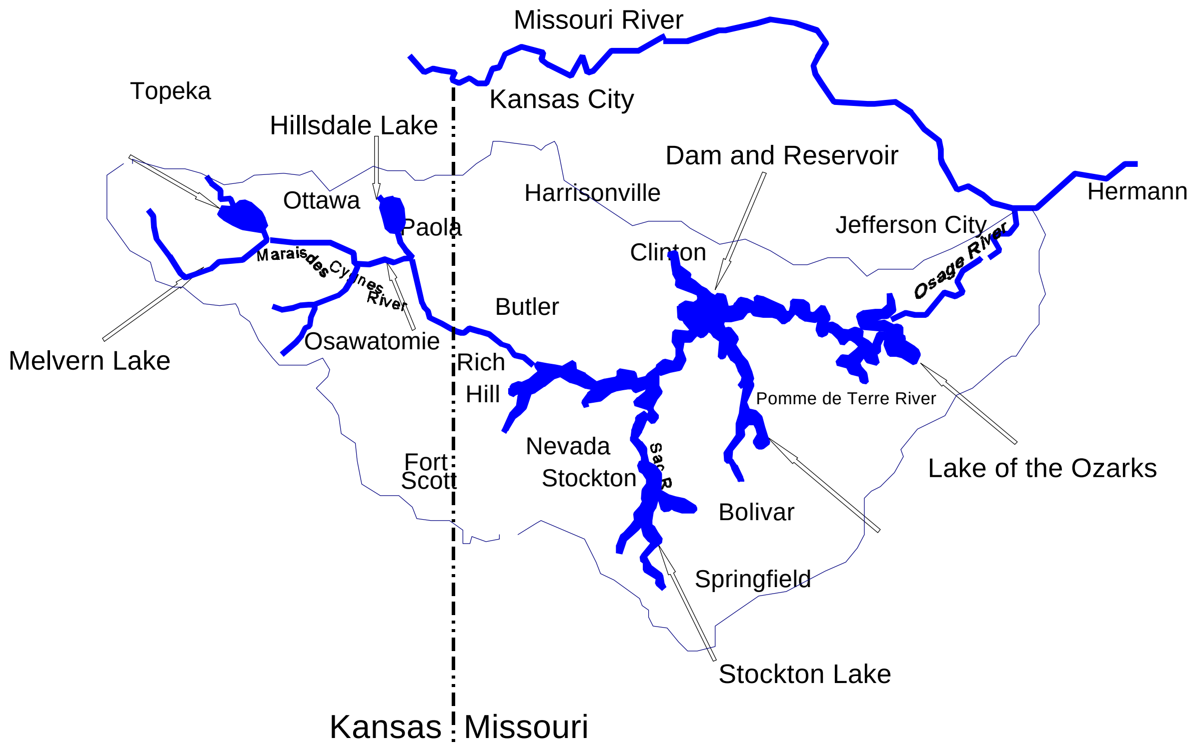
- a uniform set of principles for making water management decisions (used with local needs and data to develop solutions appropriate to a community).

- the provision of people, facilities, or money for planning and data collection.

3. **Marais des Cygnes - Osage**. The primary objective in the Marais des Cygnes-Osage was to create an interstate working group to avoid interstate conflicts over water during drought. The river is officially designated as the Marais des Cygnes from its source in east-central Kansas to its confluence with the Little Osage River near Schell City, Missouri where it becomes the Osage River and flows in an easterly direction into the Missouri River downstream of Jefferson City, Missouri. The basin is about 250 miles long, as much as 100 miles wide, with a drainage area of 15,300 square miles. A little less than a third of that area is in Kansas.

The Corps has six reservoirs in the basin; Melvern, Pomona, and Hillsdale in Kansas, Stockton, Pomme de Terre, and Harry S. Truman in Missouri. Union Electric's Lake of the Ozarks is located behind Bagnell dam, just downstream from Harry S. Truman. Union Electric uses Lake of the Ozarks for hydropower and recreation. Occasionally, in the winter months, Lake of the Ozarks supplements cooling water to a fossil fuel plant located on the Missouri River.

FIGURE M-4. THE MARAIS DES CYGNES-OSAGE RIVER BASIN



Kansas is an appropriation state with proactive water supply planning, which includes updating of a yearly water plan and partnership with the U.S. Army Corps of Engineers pursuing water storage in several Corps reservoirs. Missouri is a riparian state in which local management has historically been favored over state direction. Funding for Missouri's state water program was threatened during the DPS because of overall state budget pressures.

The potential problems in a drought situation are major impacts on power production and the recreation industry. For example, a major recreation and hydropower issue revolves around the operation of a private reservoir, Lake of the Ozarks, the most downstream reservoir in the basin. Created by Union Electric, the lake could be drawn down during a severe drought to provide electrical power to a region that includes St. Louis, Missouri. Most people in the region, however, know Lake of the Ozarks as a recreational lake and an attraction that induces tourists to spend as much as $5 million per week in the region.

During a sustained severe drought there are potential negative impacts to municipal and industrial users in Kansas and Missouri. Municipal users in Kansas include the cities of Ottawa, Osawatomie, Paola, and Ft. Scott. Municipal users in Missouri include the cities of Clinton, Springfield, Nevada, Stockton, and various Lake of the Ozarks communities. Kansas City Power and Light in Kansas uses the water to cool steam generators. Additionally, hydropower generation exists in the Harry S. Truman and Stockton Reservoirs.

Circles A and B in the Marais des Cygnes - Osage included the Corps' Kansas City District, the Kansas Water Office and the Missouri Department of Natural Resources. Each of these entities developed a portion of the shared vision model. Circle C included Kansas City Power and Light, Union Electric, Kansas Department of Wildlife and Parks, Missouri Department of Conservation, economic development commissions and water district managers within the basin.

PLANNING OBJECTIVES FOR THE MARAIS DES CYGNES-OSAGE RIVER BASIN DPS.

1. Increase the reliability of municipal and industrial water service in the Marais des Cygnes - Osage River basin.

2. Increase the reliability of recreation opportunities during drought at the 6 Federal reservoirs and 1 non-Federal reservoir in the Marais des Cygnes - Osage River Basin.

3. Increase the reliability of hydropower generation during drought at the 2 Federal and 1 non-Federal reservoirs in the Marais des Cygnes - Osage River basin.

4. Increase the dependability of agricultural production during drought in the Marais des Cygnes - Osage River basin.

Changes as a result of this DPS. This DPS was suspended during the summer of 1993 because the entire region became involved in efforts to minimize and monitor the flooding damage on the Missouri River and its tributaries.

This DPS is expected to resume in March 1994. At the time of this writing, participants from both states reported that the DPS process had helped improve understanding and cooperation between the states and the Corps, but there has been no determination of alternative plans.

D. **Cedar & Green Rivers DPS**. The Muckleshoot and Tulalip tribes fish these two rivers that supply water for the cities of Seattle and Tacoma. Droughts in 1987 and 1992 (the latter occurring during this DPS) sensitized these communities to the limits on water supply even in this northwestern rain forest.

The Cedar and Green Rivers never flow together. The **Cedar** River drains about 188 square miles south and east of Seattle. Its headwaters are on the western slope of the Cascade Mountains, from which it flows westward into Chester Morse Lake. Seattle draws about two-thirds of its municipal and industrial water from this lake. From there, the Cedar flows through Renton into Lake Washington. The Lake is used to operate the Corps of Engineers' Hiram Chittendon navigation locks (connecting Lake Washington to Puget Sound). The Cedar River provides about 70% of the total inflow into Lake Washington.

The **Green** River basin is south of the Cedar, and drains more than twice as much area (about 483 square miles). Like the Cedar, the Green starts on the western slopes of the Cascades and flows west. The Corps' Howard Hansen dam impounds up to 106,000 acre feet in the upper part of the basin, before the river flows through the Green River Valley, settled now by the communities of Auburn, Kent, Renton, and Tukwila, where it finally flows into the Duwamish River, which in turn empties into Elliott Bay in the city of Seattle.

The Corps built Howard Hansen in 1962 to provide a 100 year level of flood control, water supply for the city of Tacoma, irrigation, fish conservation and pollution abatement.

Commercial fisheries join the Muckleshoot and Tulalip tribes in a harvest of salmon and

FIGURE M-5. THE CEDAR AND GREEN RIVER BASINS

steelhead trout. Releases from Howard Hansen are adjusted to supply sufficient instream flows to maintain dissolved oxygen levels, and sufficient depths to keep fertilized fish eggs laid along the riverbank covered.

The region was ill-prepared to meet this goal when drought occurred in 1987. At this time, existing guidance for management was either limited or outdated and most personnel lacked experience in handling water shortages.

Thus, it was difficult for agencies to resolve concerns, come to consensus on an appropriate course of action, and respond to drought in a timely manner. This experience clearly demonstrated that improved mechanisms for interagency coordination during drought were needed.

Following the 1987 drought, several efforts were made statewide to improve regional drought preparedness. A state drought contingency plan was developed and drought relief legislation was enacted. Studies were initiated by the Seattle Water Department (SWD) and Tacoma Water Division (TWD) to examine ways of improving water use efficiency. Structural changes were made to the system to increase the quantity of water that could be delivered. When the DPS was initiated in 1991, stakeholders were identified and encouraged to become involved.

Circles A and B in the Cedar and Green DPS were drawn from the Corps' Seattle District, the University of Washington, the city of Tacoma, the Muckleshoot Tribe, and the

Washington Departments of Ecology and Fisheries. Circle C included the other cities in the region, including Seattle, county governments, and the Puget Sound Regional Council of Governments. The Cedar and Green River basins are distinct hydrologically, but in almost every other way they are one. Most of the principal participants in the Cedar-Green DPS have a direct stake in each basin. The Corps Seattle District manages structures on both basins, although its role is much greater on the Green. The Muckleshoot and Tulalip tribes fished both rivers for centuries, and, for the most part, the same state Fisheries and Ecology staff monitor both rivers. Although Seattle currently obtains no water from the Green, and Tacoma none from the Cedar, the cities have discussed creating an intertie between the two river basins to reduce drought vulnerability. Moreover, because the two cities each deal with the Muckleshoot's and Tulalip's, and with the same state agencies, each is attentive to the others water management programs.

Changes Resulting from this DPS. The Cedar basin model still awaits review and endorsement by the Seattle Water Department, but the contributions from the DPS have already been successfully used on the Green. The Green River basin model was first used to help agencies establish an agreed upon policy for the refill of Howard A. Hanson reservoir during March, 1993. During the spring of each year, the Corps selects a refill strategy for Howard H. Hanson Dam. Their primary objective is to refill the reservoir to achieve 98% reliability. Traditionally, the refill strategy was developed independently by the Corps, without explicit consideration of the interests of other stakeholders. However, this strategy can significantly impact the welfare of different anadromous fish species at various life stages. It can also potentially impact the water supply situation later in the season. Because of these impacts, the process for establishing a refill strategy has become more open, and an opportunity for interagency policy dialogue is now provided at an annual "refill meeting".

Typically, representatives from the Muckleshoot Indian Tribe, Washington Departments of Ecology, Fisheries and Wildlife, the Tacoma Water Division, and U.S. Fish and Wildlife are present. This meeting enables agencies to jointly assess the current water supply situation based on precipitation, runoff, snowpack and temperatures. It also provides an opportunity for fisheries agencies to suggest target instream flow levels to protect resource needs. The process of establishing a refill strategy is typically very time consuming, occurring over a period of several weeks. When modifications are suggested to the Corps initial proposal, the Corps must carefully examine their potential impacts of a proposed change. This had been done using a large mainframe model. Corps personnel reported that typically, only a few target instream flow scenarios or release strategies would be analyzed, due to time constraints. Furthermore, there was no automated approach for testing system sensitivity to different instream flow target levels.

This year, the DPS Green River basin model was used as a tool to facilitate interagency policy dialogue. Prior to the initial refill meeting several runs of the model were made to assess the impacts of:

1) different instream flow targets; and

2) different refill start dates on reservoir refill reliability.

This output was translated into a histogram to convey the potential implications of different potential policies to stakeholders. A wide range of instream flow target scenarios for the spring and summer months from agency comments at this meeting were tested using the model. The model was run over the historic record to examine the potential impact of these policies on refill. During the interagency working group meeting that followed, stakeholders used the model to fine-tune the most promising policies, by iteratively testing the impact of their modifications. In this way, they were able to develop an agreed upon management strategy within a few hours.

Overall, the model greatly facilitated the process of establishing a refill strategy. Corps representatives were extremely pleased with the model's ability to answer questions of concern to stakeholders during this process. They reported that use of the object oriented model offered several benefits in comparison to previous years:

- First, it enabled a greater number of scenarios to be investigated, and increased the amount of fine tuning that could be done.

- It provided participants with access to the entire historical streamflow database.

- It enhanced stakeholder insight to system sensitivities, and the relationship between proposed policies and their likely impacts.

- Finally, it enabled them to come to a consensus on an appropriate strategy in a straightforward manner. Because of these benefits the use of DPS Green River basin model to facilitate refill strategy development is likely to continue.

In August 1993, about twenty regional water managers representing the city of Tacoma, the Muckleshoot tribe, the state of Washington (Departments of Fisheries and Ecology) and the Corps' Seattle District used a computer model of the Green River water management system to simulate a drought so realistically that it was termed a *Virtual Drought*. These parties are now formalizing an agreement to extend the collaborative efforts of the DPS into a permanent regional water management group. Efforts to do the same on the Cedar are frustrated by the fact that the city of Seattle is about 15 months behind other study participants in reviewing and correcting the model of their system.

This study was especially useful in demonstrating the importance of getting critical players to accept a collaborative process. Most of the same players that enthusiastically accepted the DPS process on the Green were key players on the Cedar. The same modelers and managers were used on both basins. But the city of Seattle's failure to review a Cedar River model effectively stymied adoption of a collaborative approach on the Cedar.

Circles A and B in the Cedar and Green DPS were drawn from the Corps' Seattle District, the University of Washington, the city of Tacoma, the Muckleshoot Tribe, and the Washington Departments of Ecology and Fisheries. Circle C included the other cities in the region, including Seattle, county governments, and the Puget Sound Regional Council of Governments.

Other Case Studies

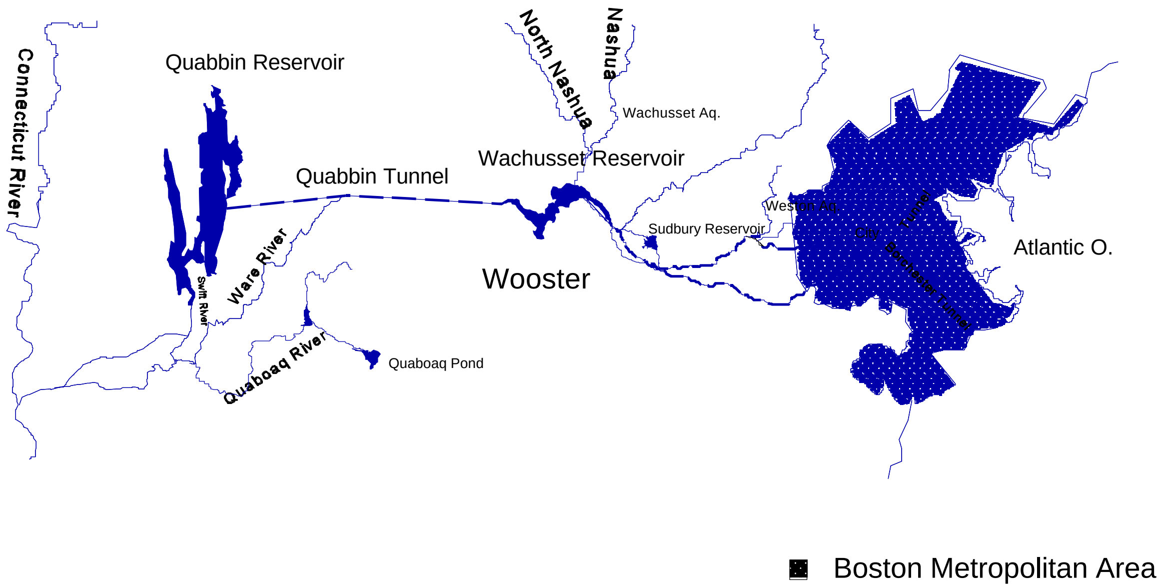
Boston Metropolitan Studies The New England Division of the Corps of Engineers worked with the Massachusetts Water Resources Authority (MWRA) and the Water Supply Citizens Advisory Committee (WSCAC) on three projects:

- the development of trigger planning using a simulation model of the MWRA system built using STELLA II.

- use of a *beta* version of IWR-MAIN 6.0 to determine the cost effectiveness of current and future demand management measures.

- a history of the MWRA, WSCAC, and other Massachusetts agencies. The purpose of the

FIGURE M-6. THE MWRA SERVICE AREA



history is to develop a basis for recommending management solutions that have worked here for other areas in the U.S.

Trigger Planning. For many years, MWRA and WSCAC have been concerned that the existing strategic planning framework does not provide sufficient flexibility to adequately assess a wide range of alternative solutions. Two primary shortcomings of the existing planning approach have been cited. First, once adopted, MWRA's strategic plans are typically not reviewed until the end of a specified planning period, often 15 to 20 years. This episodic approach does not allow the system to respond to changes in demand, regulatory requirements, and social concerns that occur during the planning period. Because corrective actions are postponed, the options to address the problems that exist at the end of the planning period may be extremely limited. A second criticism of existing strategic planning is that it is often divorced from tactical planning efforts. For example, the effectiveness of adopted drought management plans may not be considered when evaluating strategic alternatives.

Trigger Planning provides for continuous monitoring of indicators of future water supply conditions under existing management policy. Trigger planning identifies a mechanism for determining when a change in this strategy is needed. It also accounts for the impacts of existing tactical response plans in evaluating system performance from a strategic perspective. It should provide greater lead time to adequately scope and evaluate a wide range of potential alternatives, both strategic and tactical.

In the Trigger Planning Process, monitoring moves through three stages defined by pre-defined *leading indicators, critical points and triggers*. Each year, a series of leading indicators are monitored including the conditions of local sources, events and proposed projects, laws, regulations and agreements, watershed conditions and operational procedures, climate precipitation and streamflow, public views, and building permits. Although portions of this information are available in existing databases, this information must be better coordinated to effectively implement trigger planning. Next, these leading indicators are used to forecast scenarios describing future system supply and demand conditions.

Forecasts are used to estimate when the system is likely to reach a "critical" state of unacceptable performance. Currently, this critical state is defined as the condition when demand reaches a specified percentage of the system's safe yield. Eventually, multiple critical points may be defined to reflect MWRA's preferences to pursue demand management and non-structural options. The critical state for these options would occur sooner than that for non-structural options. Trigger points are then estimated by backtracking from the critical points by the estimated lead time required to implement each of the alternatives under consideration. These trigger points indicate when activities to investigate, design and implement each alternative must be initiated in order to prevent the system from reaching the critical state.

If these analyses indicate that a trigger is impending, evaluation of a wide range of alternatives would be initiated. Promising alternatives may progress through the design, environmental impact assessment, and implementation phases. During this assessment and evaluation process, however, leading indicators will be continuously monitored. Estimates of critical points and trigger points will also be readjusted to reflect this updated information. These estimates, in turn, may impact the decision to proceed with the implementation of an alternative. In this way, implementation will be postponed as late into the time horizon as possible.

Required Tools. Several computerized tools will be needed to implement the trigger planning process. Databases tracking trends in leading indicators will be established. Forecasting models will be needed for reliable estimates of demand. Other simulation models will be used to estimate system safe yield and other performance measures and to evaluate the effectiveness of alternatives at forecasted demand levels. Simulation may also be used to estimate critical points and trigger points in the time horizon.

MWRA has developed a simulation model of the system before the National Drought Study collaboration. This model was originally developed to estimate the water supply system safe yield. (Thus it has commonly become known as the Safe Yield Model). It is written in FORTRAN, and much of its logic is hard-coded in batch data files rather than specified as heuristics. The primary strength of this model is that it is trusted by stakeholders. This is because considerable effort was spent in establishing consensus among stakeholders on the model's validity.

However, the Safe Yield Model has limited potential as a trigger planning tool for a variety of reasons. Current users report that it is very difficult to modify. Thus, it would be difficult to incorporate changes in system configuration and operation that may occur over time.

Furthermore, it would also be difficult to formulate and test alternatives with this tool. Finally, Safe Yield Model output is reported in terms of a single performance measure: the number of shortfalls that occur during the simulation period. This greatly limits the perspective from which alternatives can be evaluated. Because of the perceived shortcomings of the Safe Yield model, the study group decided to use STELLA II® to create a customized trigger planning tool.

The primary focus at the early stages of model development was to replicate the existing system configuration and logic expressed in the Safe Yield Model. This required translation of the hard-coded data files into heuristics defining functional relationships among icons in the object oriented environment. Most of the information required to develop the object oriented model was found in the Safe Yield Model. A working model was completed within four months after the introductory workshop. Model validation was a two week process which was critical for establishing trust in the model. During this time, output data from the Safe Yield Model was added to the STELLA II® model for direct comparison of results. Refinements of functional relationships were made until the STELLA II® model obtained an acceptable level of agreement with the safe yield model output.

Once model validation was achieved, the working group began to explore means of enhancing the model's usefulness as a trigger planning tool. The visual clarity of the model was refined, through the use of intermediate variables and ghosts. The drought response plan, previously developed by MWRA, was incorporated into the model. Measures of system performance were also added to the model.

These enhancements were made over a period of several months, in response to suggestions made at working group meetings. During this time, model development was not the primary focus of the monthly group meetings. Rather, issues related to specific components of the trigger planning process, such as demand forecasting and the definition of critical points were emphasized in group discussion. Thus, changes to the model were made gradually, as the requirements of trigger planning were clarified.

Study participants reported that the selection of appropriate measures of system performance was one of the most difficult and time consuming aspects of model development. They devoted a great deal of effort in trying to reach agreement on which measures were most appropriate, how they should be defined and what new information they would provide. The modeling environment was extremely useful in facilitating these discussions. It enabled different measures to be quickly formulated, tested, and discarded if inappropriate.

The current model can perform simulations of system response under the current system configuration using 30 years of monthly streamflow data, containing the 1960's drought of record. The existing model would potentially be suitable for evaluating both supply and demand management alternatives in a strategic planning context. However, specific alternatives have not yet been incorporated into the model.

Finally, although study participants are enthusiastic about STELLA II, they recognize some limitations. STELLA II's lack of ability to iterate may complicate the analysis of some problems, such as hydropower sequencing. They also found the graphical capabilities of the environment to be quite limited.

Currently, five system performance measures have been incorporated into the model (see

Table L-IV). These measures were chosen as indicators of environmental quality, consumer impacts, and the quantity of water available. The performance measures were easily represented within the STELLA II® model. In contrast, it was much more difficult to establish consensus on which measures were most valuable.

TABLE L-III. PERFORMANCE MEASURES FOR STRATEGIC TRIGGER PLANNING IN THE BOSTON AREA

Category	Performance Criterion	Description
Water Quantity	Shortfall	Number of times where supply is less than the unconstrained demand. Alternatively, the volume of such a water deficit.
Environmental Quality*	Severity	The maximum number of consecutive months Quabbin reservoir is below the target pool.
	Maximum Pool Descent	The elevation of the maximum deviation of Quabbin reservoir elevation from target pool.
	Resiliency	A ratio expressed as a percentage of durations: the tolerable stay below target pool/particular stay below target pool.
Consumer Impacts	Drought Actions	The number of months at each drought restriction level.

* - as Quabbin is drawn down, there is an impact on riparian areas and water quality within Quabbin for fish habitat. Deep draw downs reduce municipal water quality.

During the course of the study, the model has been used to examine the impact of drought management on system performance and to predict system performance for the year 2012 under four different demand scenarios.

The model has also influenced the formulation of performance measures in the trigger planning framework. Had the model not been available it is unlikely that the same measures would have been chosen. Furthermore it is unlikely that the implications of these measures would be as well understood. Study participants reported that their model-aided investigation of performance measures greatly enhanced their understanding of the trade-offs involved in system operation.

It is likely that the model will continue to be used in the definition of the trigger planning framework. For example, it may help participants reach consensus on the points when these measures indicate an unacceptable level of system performance. Such discussions will likely lead to the refinement of the definitions used for critical points, and will provide guidance for future assessment of alternatives within the trigger planning framework.

Activities Anticipated Beyond the Study. Although Corps involvement in the trigger planning effort ceased upon completion of the National Drought Study, much work remains. Both MWRA and WSCAC are confident that both the trigger planning paradigm and model content will continue to be refined, largely because of the success of the efforts so far. Likely activities include further enhancements to equation documentation and model clarity. Demonstrations of the trigger planning concept and the object oriented model to a larger audience within MWRA, WSCAC and the Corps, and other interested agencies will occur. IWR-MAIN will be brought on line to improve the quality of the demand forecasts required of the trigger planning process.

Trigger planning will begin to be integrated into future planning documents and is anticipated to become the accepted agency planning approach. The existing model will be used annually to perform the trigger planning analyses. As trigger points are approached, the model will be adapted to analyze a wide range of potential alternatives. WSCAC has also expressed an interest in using this model to reevaluate the adequacy of the triggering mechanisms in MWRA's existing drought response plan.

Susquehanna River Basin Studies. This work was a series of small efforts done in parallel with an ongoing Section 22 study of water supply in Harrisburg area. The collective work had five components: an examination of the condition of small water supply systems; an investigation of differences between public and investor owned utilities' drought contingency plans; a brief review of vulnerability to drought; a look at the possibilities for conjunctive management of surface and groundwater, and the development of a preliminary shared vision model of the Susquehanna River in collaboration with the Susquehanna River Basin Commission (SRBC). The studies found that regionalization of water supplied would help efforts to meet water quality and drought preparedness needs. There were few differences between the drought preparedness plans of public and private water utilities; all were formulaic. SRBC has since purchased computer equipment and software to continue the development of the shared vision model. The Baltimore District is aiding this effort as part of the Planning Assistance to States (Section 22). The objective in this work is unusual; the SRBC feels that current drought management techniques may be too frequently imposed, and intend to use a shared vision model and Atlas statistics to demonstrate that.

Colorado River Gaming. *Gaming* is the technique of placing subjects in an environment which requires them to make joint or collective decisions among hypothetical options. The subjects are shown the prospective consequences of their decisions as the game proceeds. Playing the game can improve one's understanding of how a water system responds to different water management decisions, and may reveal changes in operating rules which improve the performance of the system.

The Colorado River Gaming study was part of a larger effort called the Study of Severe Sustained Drought in the Southwestern United States (the SSD Study), which was conducted by a consortium of western U.S. universities. The purpose of the SSD research program was to identify feasible changes in operating rules for allocating and managing Colorado River water. The SSD Study was supported by funds from the USGS, the Metropolitan Water District of Southern California, the Upper Colorado River Commission, the National

Drought Study and the participating universities. The SSD Study grew out of the U.S. State Department's "Man and Biosphere Program".

The Colorado Gaming Study was a collaborative effort between the SSD and the National Drought Study teams. Bill Lord (University of Arizona) was the principal architect and proponent for the game. Like the Drought Study, the Gaming Study was designed to connect research and practice, and both kinds of water experts participated. State water officials from the Colorado basin served as study advisors, while students and professors played the roles of officials and applied the research and findings from the SSD Study to the game.

The objectives of this gaming exercise were to screen alternative *operating* rule sets before a more detailed evaluation, and to compare alternative *collective choice* rule sets. (See page 8 in the main report for definitions of the three levels of rules). An analysis using game theory helped define the three collective choice rule sets which distinguished the 3 games. (Gaming is distinct from, but can be used in conjunction with the mathematical *theory of games*. John von Neumann and Oskar Morganstern developed game theory as a method for analyzing competitive situations in economics, warfare, and other areas of conflicting interest (Glicksman).)

The gaming exercise was first done as a graduate seminar in the Spring term of 1992 at the University of Arizona. Seven graduate students assumed the roles of state water officials from the seven states of the Colorado River Basin, and chose how they would respond to a severe drought as it unfolded through the simulation of AZCOL. AZCOL was a model of the hydrology, water management facilities, water allocation institutions, and water demands of the basin. AZCOL was developed using STELLA II®. The choices the students could make were limited; some were intrastate, others were interstate and required two or more students to come to an agreement to act. The game was played nine times, each time with unique set of rules.

A second game was played in June 1993 with university professors from each state playing the role of water directors, and study advisor playing the role of the Secretary of the Interior. The game was based on a very severe 38 year drought (on the order of a 500 year event), and was played three times under three collective choice alternatives:

- **The Status Quo Game**, in which operating decisions for water management facilities were made by the Department of the Interior in accordance with existing rules. Any changes in the rules required unanimous agreement by DOI and the seven states. This alternative is marked by limited information about consequences, especially to other states. The players used e-mail to conduct this game so as to prevent face to face bilateral negotiations.

- **Colorado River Basin Commission Game**. A river basin commission would provide many of the advantages of an interstate compact, but could be established more easily, so this option was simulated in the second game. The rules for the Commission Game were identical to the Status Quo game except that the "Commission" shared more information and analyses with the states, and the players assembled in one location for this game. This meant they could take part in group discussions (no bi-lateral discussions were allowed) on decision making and alternative decision rules. Given this framework, players developed an alternative to the "equalization rule", the status quo method of balancing hydropower production from Glen Canyon Dam and water deliveries to the Lower Colorado Basin.

- **Water Banking and Marketing Game**. This differed from the Commission Game in that any two states could exchange unlimited amounts of information, and could make bilateral agreements (including interstate sale of water) so long as the other 5 states were not harmed. The judgement of no harm was made by the "Secretary of the Interior".

In each game, participants had freedom to make changes in operating rules within the applicable collective choice rule set. Players identified the important measures of performance (primarily, amounts of water delivered) and decision criteria. Before the games were played, decision criteria were evaluated for relative importance using the Bureau of Reclamation's MATS software. In general, the *pre-game* subjects rated economic impacts twice as important as equity, and endangered species preservation more important than maintenance of wetlands and riparian areas. These inferences were important for the game, but have little significance out of that context, since these values were elicited from professors playing the role of state water directors.

This study showed that:

- In this simulation, water managers were most interested in satisfying diversions for consumptive use and avoiding impacts that would trigger action under the Endangered Species Act. Hydropower production, recreation, salinity, and most non-ESA environmental impacts were less important.

- There is sharp competition among water uses on the Colorado, and the Status Quo does not provide clear decision criteria for allocation. The water use priorities of the "Law of the River" are further complicated by independent rules implicit in the Endangered Species Act, the Clean Water Act, and federal reserved rights. And, in these three games, the economic value of hydropower was not matched by an equivalent priority for waters. (See page L-6 for a real world verification of this discrepancy between economic impact and water management priority).

- Consumptive water uses are well protected from drought, but non-consumptive uses are not. Drought risk is the highest in the upper basin.

- Only minor changes can be made under existing rules, and only minor improvements can be made with the other two collective choice rule sets, so long as changes in federal legislation or court decisions are ruled out.

- Intrastate drought management is more effective in limiting drought losses than are easily adopted changes in interstate water allocation.

The games suggest the value of a compact commission, perhaps similar to the Delaware River Basin Commission, that would examine a re-balancing of consumptive and non-consumptive uses facilitated by water banking and marketing.

Finally, the gaming exercise demonstrated a complete method for testing and reporting on institutional changes.

N - The National Drought Atlas

The National Drought Atlas is a compendium of statistical information. It was designed to help regional analysts answer certain questions more quickly and with more confidence than ever before. The Atlas can be used for to help determine how long and intense droughts are likely to be, both for the sake of long term planning and operational decisions during a drought.

The development of the Atlas was a collaborative effort among the Corps of Engineers, Miami University (Ohio), the National Climate Data Center (NCDC), and International Business Machines (IBM). The Atlas team was headed by Dr. Gene Willeke, Institute of Environmental Sciences, Miami University, Oxford, Ohio. The principal researchers were Nathaniel Guttman, National Climatic Data Center, Asheville, N.C., Jonathan Hosking and James Wallis, both of the I.B.M. Thomas J. Watson Research Center, in Yorktown Heights, N.Y.

The Atlas is based on recently refined national precipitation and streamflow data sets. Precipitation and streamflow statistics were generated using a method (referred to as *l-moment analysis*) developed at IBM by J.R. Hosking and J.R. Wallis. The method permits greater confidence in estimating drought frequencies from the relatively small number of droughts for which there are precipitation and streamflow records.

The Atlas includes statistics in three categories: precipitation, streamflow and Palmer Index. To aid the user in applying these statistics, the Atlas includes:

- A map of the U.S. showing average annual precipitation. (The map is the first national precipitation map since 1962, and is based on the HCN.)

- A United States map showing the precipitation clusters

- A United States map showing the precipitation stations

- A United States map showing the streamflow stations

- Explanations of the methods and data, and a summary of implications for water policy and management.

A short description of the Atlas' information on precipitation, streamflow and Palmer Index follows, with examples.

- **Precipitation**. The Atlas has tables and graphs showing the percentage of normal precipitation that can be expected for a variety of durations and starting months at various frequencies for 111 "clusters" covering the contiguous 48 states. The frequencies are 0.02, 0.05, 0.10, 0.20, 0.5, 0.80, 0.90, 0.95, 0.98. The expected frequencies of hydrologic events are also expressed in terms of return or recurrence intervals, such as "a 50 year event". The implication of the phrase is not that the event will return, comet-like, on a 50 year schedule, but that over a very long period of time, there would be an average of two events at least that large per century. The Atlas frequencies span a range from 0.02, a "50 year dry period", to 0.98, a "50 year wet period." The probability of greater than normal precipitation can help estimate the likelihood that soil moisture or reservoir levels will recover within a given amount of time. The durations are 1, 2, 3, 6, 12, 24, 36, and 60 months. For durations of 1, 2, 3 and 6 months, the percentage of normal precipitation is provided for each starting month from January through December. Researchers found that for longer durations, *quantiles* (the ratio of the extreme to the median event of the measured statistic, such as volume of precipitation) were about the same no matter the starting month.

These statistics represent the estimated population based on a regional frequency analysis of the 1,119 stations in the Historical Climatology Network (HCN). The HCN is composed of verified data for precipitation stations with long historic records, and was developed by the National Oceanographic and Atmospheric Administration (NOAA) for use in climate change studies.

Example. This illustration is meant to show the practical use of the Atlas data, not to demonstrate their mathematical soundness. Statistical explanations for the development methods are discussed in the Atlas and in the peer reviewed papers that preceded its publication.

Drought planners often use the worst drought on record to test the merits of their plans. But how likely is it that there will be a more intense or a longer drought than the drought of record? The Atlas would allow an analyst to estimate the probability that there will be less precipitation during future droughts than during the drought of record.

To do that, the analyst would first characterize the drought of record in terms comparable to the durations and starting months in the Atlas. For example, if the worst drought on record occurred from 1932 to 1936, the analyst would collect precipitation records for all sites of interest, and then calculate the median 5 year precipitation (in inches), the 1932-36 precipitation totals, and the ratio of the 1932-36 to the median for those stations. Assume for this illustration that the ratio of the two varied at different precipitation stations from 0.84 to 0.88. (That is, 83-86% of the median 5 year precipitation fell during the 30's drought at those stations.) The analyst would then compare these ratios to the quantiles for various recurrence intervals shown in the Atlas. In the process outlined below, the analyst would find that the Atlas 50 year quantile for 60 month duration is 0.83; the 20 and 10 year droughts are 0.86 and 0.89, respectively. That would mean that precipitation amounts as small or smaller than the 30's drought should be expected every 10 to 50 years, depending on the station. The implication for a planner in this hypothetical situation is that a more severe 60 month drought is probable within any fifty year period.

To develop the Atlas quantiles, the analyst would first look at the Atlas' U.S. map that shows the 111 precipitation clusters, and select the clusters that spanned the study area in question. For this illustration, assume that those clusters are 35, 105, and 106. Cluster 35 covers the western panhandle of Florida, Southwestern Alabama, Coastal Mississippi, and Southeastern Louisiana. It is made up of 17 precipitation stations.

Table N-I lists the defining characteristics of the 17 stations in Cluster 35. The Atlas includes these characteristics for all clusters.

Each precipitation station in a cluster has the same population distribution about the median. For example, the ratio of the 50 year to the median precipitation for any station in Cluster 35 is the same for each duration. The quantiles for Cluster 35 are shown in Table N-II. For example, the amount of precipitation that can be expected in a 60 month drought with a 50 year recurrence interval is 83% of the median precipitation for the year. This would apply to all stations in Cluster 35. An analyst would usually want to estimate probable precipitation amounts at stations not included in the Atlas. The Atlas

TABLE N-I. STATION DESCRIPTIONS IN CLUSTER 35

Station Number	Station Name	State	Latitude	Longitude	Elevation
11084	Brewton 3SSE	AL	31.07	87.05	85
128132	Fairhope	AL	30.55	87.88	23
80211	Apalachicola WSO AP	FL	29.73	85.03	20
82220	DeFuniak Springs	FL	30.73	86.12	230
86997	Pensacola FAA AP	FL	30.47	87.20	112
160205	Amite	LA	30.70	90.53	170
160549	Baton Rouge	LA	30.53	91.13	64
162151	Covington 4 NNW	LA	30.53	90.12	40
162534	Donaldsonville	LA	30.07	91.03	30
163313	Franklin 3 NW	LA	29.92	91.55	12
164407	Houma	LA	29.58	90.73	15
164700	Jennings	LA	30.20	92.67	25
165026	Lafayette	LA	30.20	91.98	38
166664	New Orleans Audubon	LA	29.92	90.13	6
169013	Thibodaux	LA	29.77	90.78	15
220792	Pascagoula	MS	30.40	88.95	12
227128	Poplarville EXP STN	MS	30.85	89.55	313

TABLE N-II. QUANTILES FOR CLUSTER 35, NATIONAL DROUGHT ATLAS.

	50[1]	20	10	5	← Dry Wet →	5	10	20	50	
	0.02[2]	0.05	0.10	0.20	0.50	0.80	0.90	0.95	0.98	Mean
12[3]	0.65[4]	0.71	0.77	0.85	1	1.19	1.28	1.37	1.47	1.01
24	0.75	0.80	0.84	0.89	1	1.12	1.19	1.24	1.30	1.01
36	0.79	0.83	0.87	0.91	1	1.09	1.14	1.18	1.23	1.00
60	0.83	0.86	0.89	0.92	1	1.07	1.12	1.12	1.19	1.00

1 - recurrence interval, in years (up to 50 year dry or wet events)
2 - the non exceedance frequency; the percentage of time it will *not* precipitate more than this
3 - duration, in months (from 12 to 60)
4 - the values in the table are quantiles, the ratio of the precipitation in the extreme event to the median event. In the case of the quantile footnoted, the table implies that in only 2% of all years will less than 65% of the median precipitation fall in stations associated with Cluster 35.

quantiles would also apply to most of those stations. The analyst would make a professional judgement about which precipitation stations not included in the Atlas should be associated with Cluster 35, 105, or 106. In most areas of the country, there will be little difference in the quantiles of adjoining clusters for similar events of the same duration and rarity. The practical implication is that if the analyst were to associate a non-Atlas station with the "wrong" cluster, the estimated precipitation would still be about the same. This is evident when the quantiles for the 3 clusters in this example are compared for 12 month long events (Figure N-1) and 60 month events (Figure N-2). The 60 month duration quantiles for the 20 and 50 year recurrence intervals are 0.01 higher for Clusters 105 and 106 than for Cluster 35, equivalent to about two inches of precipitation in five years.

TABLE N-III. QUANTILES FOR CLUSTERS 105 AND 106

Cluster 105

	50[1]	20	10	5	← Dry Wet →	5	10	20	50	
	0.02[2]	0.05	0.10	0.20	0.50	0.80	0.90	0.95	0.98	Mean
12[3]	0.70[4]	0.75	0.80	0.87	1	1.18	1.27	1.35	1.45	1.01
24	0.78	0.82	0.87	0.92	1	1.14	1.21	1.27	1.32	1.01
36	0.81	0.84	0.88	0.92	1	1.10	1.15	1.20	1.25	1.01
60	0.84	0.87	0.89	0.92	1	1.07	1.12	1.12	1.21	0.99

Cluster 106

	50[1]	20	10	5	← Dry Wet →	5	10	20	50	
	0.02[2]	0.05	0.10	0.20	0.50	0.80	0.90	0.95	0.98	Mean
12[3]	0.70	0.75	0.80	0.87	1	1.18	1.27	1.35	1.45	1.01
24	0.77	0.81[4]	0.85	0.90	1	1.12	1.19	1.24	1.31	1.01
36	0.80	0.83	0.86	0.91	1	1.10	1.15	1.18	1.21	1.00
60	0.84	0.87	0.90	0.93	1	1.07	1.10	1.10	1.17	1.00

1 - recurrence interval, in years (up to 50 year dry or wet events)
2 - the non exceedance frequency; the percentage of time it will *not* precipitate more than this
3 - duration, in months (from 12 to 60)
4 - the values in the table are quantiles, the ratio of the precipitation in the extreme event to the median event. In the case of the quantile footnoted, the table implies that in only 5% of all two year periods will less than 81% of the median precipitation fall in stations associated with Cluster 106.

FIGURE N-1. PRECIPITATION QUANTILES FOR 3 CLUSTERS IN THE SOUTHEAST

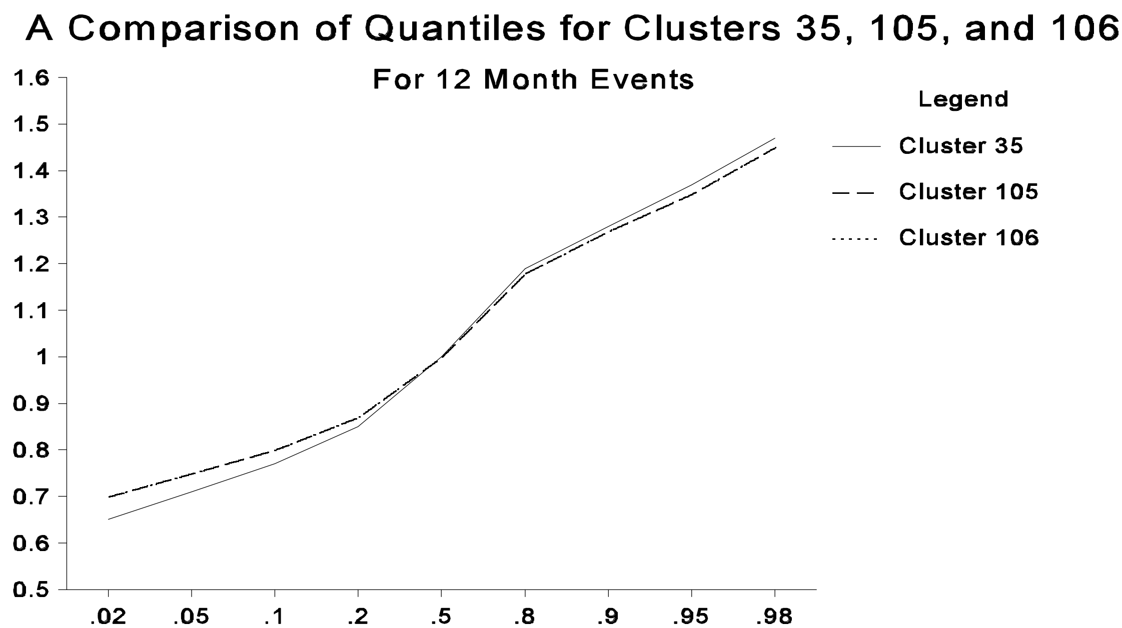


FIGURE N-2. QUANTILES FOR 60 MONTH DROUGHTS IN 3 CLUSTERS

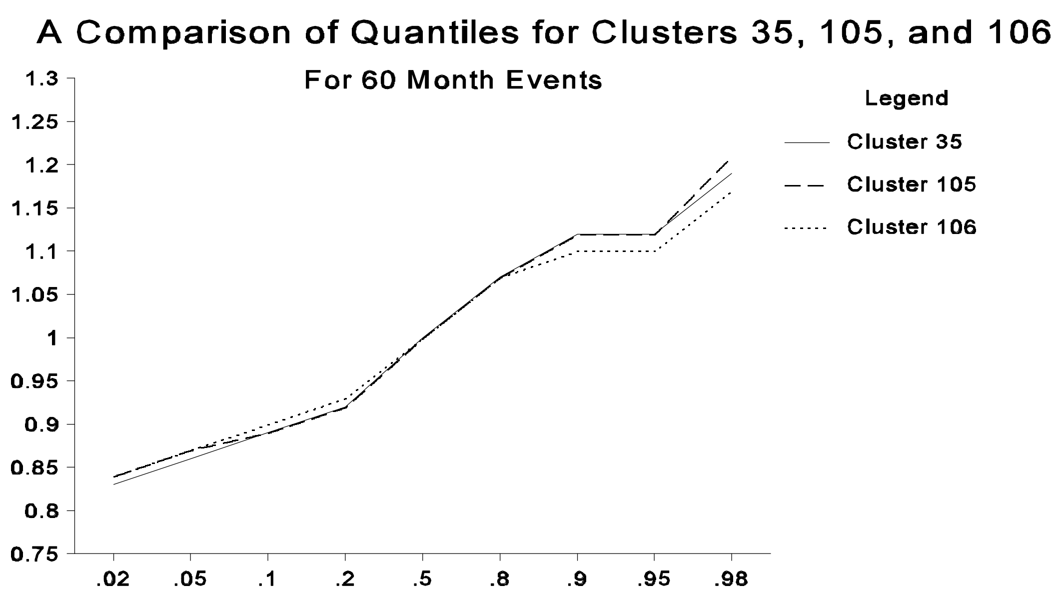


TABLE N-IV. MEAN PRECIPITATION FOR STATIONS IN CLUSTER 35.

Precipitation Station No.	Mean Precipitation for a period of:			
	12 months	24 months	36 months	60 months
11084	62.23	124.42	186.64	311.27
128132	64.79	129.59	194.33	323.97
80211	56.25	112.44	168.67	280.76
82220	66.73	133.13	200.02	333.28
86997	60.42	120.84	180.53	302.11
160205	63.65	127.30	190.84	317.33
160549	57.72	115.45	173.18	286.18
162151	61.99	124.28	185.01	303.14
162534	59.29	118.81	177.50	296.36
163313	64.11	128.61	191.79	320.92
164407	62.22	124.05	187.45	311.37
164700	58.77	117.49	176.18	293.58
165026	57.61	114.95	172.58	287.91
166664	61.29	122.34	183.53	305.11
169013	63.14	126.29	190.51	315.92
220792	59.73	118.68	177.52	295.95
227128	62.5	124.10	186.73	308.96

Expected amounts of precipitation for each frequency, duration, and starting month can also be calculated. Table N-IV lists the mean precipitation for 12, 24, 36, and 60 months for the stations in cluster 35. This information is also included in the Atlas. Multiplying the mean by the product of the 50 year quantile and the ratio of the median to the mean (which is often 1.00) produces the expected depth of precipitation for a 60 month duration, 50 year recurrence interval drought. These depths are shown in Table N-V.

- **Streamflow**. The Atlas includes tables and graphs showing the percentage of normal streamflow that can be expected at various frequencies for durations of up to 12 months at individual gaging stations in the 48 contiguous states.

The frequencies are the same as for precipitation: 0.02, 0.05, 0.10, 0.20, 0.5, 0.80, 0.90, 0.95, and 0.98. These statistics represent the estimated population based on an *at-site* frequency analysis for a subset of the Historical Climatological Data Network (HCDN), developed by the U.S. Geological Survey. Table N-VI and Table N-VII show a sampling of streamflow stations and data in the same geographic region used for the precipitation example. The analysis would be performed in essentially the same way as the precipitation example. The resultant flows would be equivalent to unregulated flows, and would have to be adjusted to reflect recent changes in the water management regime.

TABLE N-V. EXPECTED PRECIPITATION IN A 50 YEAR DROUGHT, CLUSTER 35.

Station Number	12 month	24 month	36 month	60 month
11084	40.4	93.3	147.4	258.4
128132	42.1	97.2	153.5	268.9
80211	36.6	84.3	133.2	233.0
82220	43.4	99.8	158.0	276.6
86997	39.3	90.6	142.6	250.8
160205	41.4	95.5	150.8	263.4
160549	37.5	86.6	136.8	237.5
162151	40.3	93.2	146.2	251.6
162534	38.5	89.1	140.2	246.0
163313	41.7	96.5	151.5	266.4
164407	40.4	93.0	148.1	258.4
164700	38.2	88.1	139.2	243.7
165026	37.4	86.2	136.3	239.0
166664	39.8	91.8	145.0	253.2
169013	41.0	94.7	150.5	262.2
220792	38.8	89.0	140.2	245.6
227128	40.6	93.1	147.5	256.4

TABLE N-VI. STATISTICS FOR SELECTED STREAMGAGE STATIONS

		50 year (dry)		50 year (wet)	
Number	Description	1 month (March)	12 month	1 month (November)	12 month
2411800	Little River Near Buchanan, GA	0.13[1]	0.50	2.52	1.41
2414500	Tallapoosa River at Wadley AL	0.18	0.52	2.90	1.72
2331000	Chatahoochee River near Leaf, GA	0.39	0.58	2.65	1.59
2331600	Chatahoochee River near Cornelia, GA	0.28	0.32	2.40	1.42

1 - implies that in only 2% of all March’s (50 year recurrence interval) will there be less than 13% of the median precipitation for March.

TABLE N-VII. SOME SOUTHEASTERN STREAMGAGE STATIONS LISTED IN THE ATLAS

Station Number	Drainage Area (Sq.mi.)	Elevation	Annual Precipitation	Latitude	Longitude
2411800	20.2	1230	51	33.8	85.12
2414500	1675	930	52	33.12	85.56
2331000	150	1950	62	34.58	83.64
2331600	315	1871	62	34.54	83.62

TABLE N-VIII. THE PERCENTAGE OF THE HISTORIC RECORD THAT THE PDSI WAS -3 OR DRIER FOR CLUSTER 35 STATIONS IN ALABAMA.

Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec	Mean
2.9	1.4	4.3	4.3[1]	5.8	4.3	7.2	8.7	7.2	8.7	7.2	4.4	5.5

1 - implies that the Palmer Drought Severity Index was -3 or lower in 4.3% of all April-May periods on record for this Cluster in Alabama. Unlike streamflow and precipitation, the PDSI percentages in the Atlas are *sample*, rather than *population* statistics.

- **Palmer Index**. The Atlas includes tables showing the percentage of time in the historic record that the Palmer Drought Severity Index (PDSI) fell below -3, -4, and -5. The PDSI was calculated at 1,135 precipitation stations, including all of the HCN stations. These are at-site *sample* statistics; no population distributions were estimated. As an example of the PDSI information in the Atlas, Table N-VIII shows the percentage of time the PDSI was below -3 in Cluster 35 for at least two months.

Interagency cooperation on design of the Atlas. A number of scientists and engineers helped guide the initial design of the Atlas, including Robert Brumbaugh, IWR; Ernie Carlson, IWR; Dick DiBuono, Corps of Engineers; Michael Fosberg and William Sommers, Forest Fire & Atmospheric Sciences Research, US Forest Service; Ken Kunkel, Director, Midwest Climate Center, Champaign, IL; Lou Moore, Bureau of Reclamation; Arlene Nurthen, Director of Publications, IWR; Tom Ross, USGS; Norton Strommen, Chief, Climatology; Wilbert Thomas, USGS; John Vogel, National Weather Service; Ann Carey, Chief Science Advisor, Soil Conservation Service, and Gene Stallings, Office of Hydrology, National Weather Service. An early version of the Atlas was presented to a group of water managers who recommended that the frequencies of extreme wet as well as dry periods be estimated so that they would have additional information to help respond to questions about *recovery* from a drought. Those managers include Richard Punnett (Huntington district Corps of Engineers), Brian Spindor (Seattle Water Department) Chris Lynch (Seattle district Corps of Engineers), and

Stu Schwartz (Interstate Conference on the Potomac River Basin).

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The National Study of Water Management During Drought: Report on the First Year of Study (IWR Report 91-NDS-1) prepared by the Institute for Water Resources, U.S. Army Corps of Engineers, Fort Belvoir, Virginia.

A Preliminary Assessment of Corps of Engineers Reservoirs, Their Purposes and Susceptibility to Drought (IWR Report 91-NDS-2), prepared by the Hydrologic Engineering Center, U.S. Army Corps of Engineers, Davis, California.

An Assessment of What is Known About Drought (IWR Report 91-NDS-3) prepared by Planning Management Consultants, Ltd., Carbondale, Illinois.

Lessons Learned from the California Drought (1987-1992) (IWR Report 93-NDS-5) prepared by Planning and Management Consultants, Ltd., Carbondale, Illinois.

Executive Summary: Lesson Learned from the California Drought 1987-1992 (IWR Report 94-NDS-6) is a concise summary of NDS-5 (above), with some new information that became available after NDS-5 was published.

Computer Models for Water Resources Planning and Management (IWR Report 94-NDS-7) summarizes brand name models in eight categories: general purpose software (such as spreadsheets), municipal and industrial water use forecasting, water distribution systems (pipe networks), groundwater, watershed runoff, stream hydraulics, river and reservoir water quality, and river and reservoir system operations.

National Study of Water Management During Drought: Report to Congress (IWR Report 94-NDS-12) summarizes the results of the entire study.

Other reports will be published:

The National Drought Atlas (IWR Report 94-NDS-4) is a compendium of statistics which allows regional water managers to determine the probability of droughts of a certain magnitude and duration.

Drought Impacts in a P&G Planning Context (IWR Report 94-NDS-9)
Human and Environmental Impacts: California Drought 1987-92 (IWR Report 94-NDS-10) NDS-9 is a collection of papers by California researchers who attempted to measure the impacts of the drought on the California economy and environment. NDS-10 shows how drought impacts can be measured in the accounting system of Principles and Guidelines. It uses the results of NDS-8 as an example.

Water Use Forecasts for the Boston Area Using IWR-MAIN 6.0 (IWR Report 94-NDS-11) demonstrates one of the first uses of a beta test version of the new generation of MAIN. The objective of this study was to determine the relative effectiveness of long term water conservation measures.

Trigger Planning for the MWRA Service Area (IWR Report 94-NDS-13) documents the development of what might be called "just in time" water supply enhancement; a management system that can reduce economic and environmental investments in supply and demand measures while maintaining necessary water supply reliability.

Governance and Water Management During Drought (IWR Report 94-NDS-14). Prepared by the Advisory Commission on Intergovernmental Relations (ACIR). NDS-14 addresses the general subject of technical water management within the American democratic process. It includes papers on law, decision making, public involvement, and two case studies that provided information on political decision criteria to water managers.

Colorado River Gaming Exercise (IWR Report 94-NDS-15) documents the use of a shared vision model in a gaming exercise to evaluate operational and institutional alternatives for the management of the Colorado River. This report was prepared as a joint project with the Study of Severe Sustained Drought in the Southwest United States.

Shared Vision Models and Collaborative Drought Planning (IWR Report 94-NDS-16), prepared by the University of Washington for the Corps of Engineers, documents the use of the shared vision model in the National Drought Study case studies.

Lessons Learned from the National Drought Study Case Studies will be published contingent on the completion of the Marais des Cygnes-Osage DPS, which was delayed by the flooding on the Missouri River during the Summer of 1993.

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