PLANNING FOR DROUGHTS: NEW CONSIDERATIONS CALL FOR NEW STRATEGIES

Ben Dziegielewski *

Introduction

Adequate community water supply is an essential service which ensures public health and safety, economic activity, and a general community well-being. Yet, hundreds of municipalities across the country had their water supplies threatened by the four droughts of this decade: 1981, 1985, 1986 and 1988. Many more communities may experience water shortages in the future even during the times of normal rainfall. For these communities, the much feared change in climate attributed to the "greenhouse effect" does not have to materialize to bring about water shortages. Scarcity of water in some areas of the country is a reality which calls for reexamination of our traditional approach to planning for urban water supply. The thesis of this paper is that the traditional approach to drought mitigation has not worked too well in the past and is even less likely to work in the future. There are some new considerations in urban water supply planning which call for new strategies for mitigating the effects of droughts and to avert the threat of permanent shortages of water supply. An example of a new practical approach to drought planning is presented.

The Traditional Approach

The traditional approach to urban water supply planning has evolved during the past 60 years as urban areas have expanded their water works and related facilities. Rapid urban growth has made it possible to design and build water facilities with substantial extra capacity to accommodate population growth and industrial development. Construction programs of urban water supply agencies were developed based on (1) a simple projection of future water requirements; (2) identification of adequate sources of supply; and (3) a design of the necessary transmission, treatment, storage and distribution facilities. Civil engineers responsible for the design of water works viewed the problem of drought as one that is specifically related to hydrologic variability. Understandably, they pursued those solutions which would reduce the variability of supply. From such a perspective, the simplest form of the adjustment to drought involved the provision of "sufficient" storage of water in times of average or high rainfall for use during periods of drought. The sufficient storage was usually determined using the concept of "design drought." The design drought for a given stream-reservoir system was often represented by the worst drought in the historic record. In other words, the storage system was designed to provide adequate supply during the worst recorded drought. The output of a supply system that can be maintained during the design drought is known as system's "safe yield." The safe yield implies that no shortage of water will be experienced during droughts less severe than the design drought.

Naturally, the safe yield strategy does not protect against all droughts. In reality it does not protect water systems even from mild droughts, i.e., droughts which are less severe than the design drought. Because water managers do not know the length and severity of an ongoing drought, they have no way of knowing whether their supplies are safe. Water agencies that carry the burden of responsibility for uninterrupted supply usually take some emergency actions in order to minimize the risk of running out of water. These actions, whether they are aimed at increasing supply or reducing demand, always carry a price tag. Thus, the extra capacity solution may provide a sense of security, but few water agencies will wait to find out whether their safe yield is really safe.

---

*Assistant Professor, Department of Geography, Southern Illinois University at Carbondale, Carbondale, Illinois

New Considerations

Although the provision of extra storage capacity remains one of the most popular measures for mitigating droughts, some new economic, social and environmental considerations place this alternative beyond the reach of many water agencies. First, there is a limited availability of untapped sources of supply. Many urban areas, especially in the west, have begun to experience water allocation problems as regional surface supplies have become fully appropriated and groundwater aquifers have become depleted. Acute or chronic source contamination, particularly groundwater sources, further limits water availability. Also, large-scale water transfers between river basins or across political boundaries are often not feasible due to legal, political and environmental constraints. Second, the increasingly stringent water purity standards have led to a significant increase in the cost of water treatment and in some cases water sources that served communities for decades are no longer adequate because of excessive contamination. Third, the prospects for financing major construction programs are discouraging in many public utilities. Water supply often competes for funds with other essential municipal services. It is at a disadvantage in this competition because of its high investment requirements and traditionally low revenues due to subsidized pricing. Finally, new environmental legislation has severely constrained the opportunities and alternatives in urban water supply. Water supply development has to be coordinated with wastewater planning and any major construction of water facilities is subject to extensive review and regulation. Also, the increasing general concern for environmental quality has resulted in a more active role of the public in resource management decisions. The need for new supply development receives unprecedented scrutiny from environmental groups and even projects that are partially completed are stopped because of their potential environmental impacts.

These new considerations have forced water planners to extend their perspective beyond traditional supply augmentation projects. In recent years, a number of unconventional supply alternatives have been considered including: (1) more efficient utilization of existing water supplies (e.g., pumped storage or reduction of losses through lining of reservoirs or evaporation suppression); (2) use of groundwater aquifers for storage of excess supply of surface water; (3) desalinization of sea water or brackish groundwater, (4) reclamation of wastewater for both potable and non-potable uses; and *(5)* increasing runoff through watershed management or cloud seeding.

However, the most profound change in water supply planning involves the use of demand management alternatives. These new considerations in combination with some new federal policies makes demand management a viable alternative to supply augmentation. The demand management projects that can substantially reduce future water use may include the following:

(1) Public campaigns to educate the consumers on how to modify water use habits to reduce water consumption

(2) Promotion or a mandatory requirement of use of water-saving devices and appliances

(3) Promotion or a mandatory requirement of low-water-using urban landscaping

(4) Adoption of efficient marginal cost pricing strategies to discourage inefficient uses of urban water

(5) Adoption of zoning and growth policies to control the number of water users served by the system

A combination of supply augmentation and demand management projects has the potential for providing adequate future water supply at the minimum cost. However, the change in the approach to urban water supply planning calls for some new and appropriate methods for analyzing and evaluating the unconventional alternatives. Some of the most needed new tools of a water planner include: (1) improved methods of forecasting urban water demand; (2) evaluation of social, environmental and economic impacts of water conservation measures; and (3) methods for drought planning that involve integrating capacity expansion with demand reduction projects. The remainder of this paper presents a planning framework for a systematic evaluation of a broad range of long-term and short-term measures for drought mitigation.

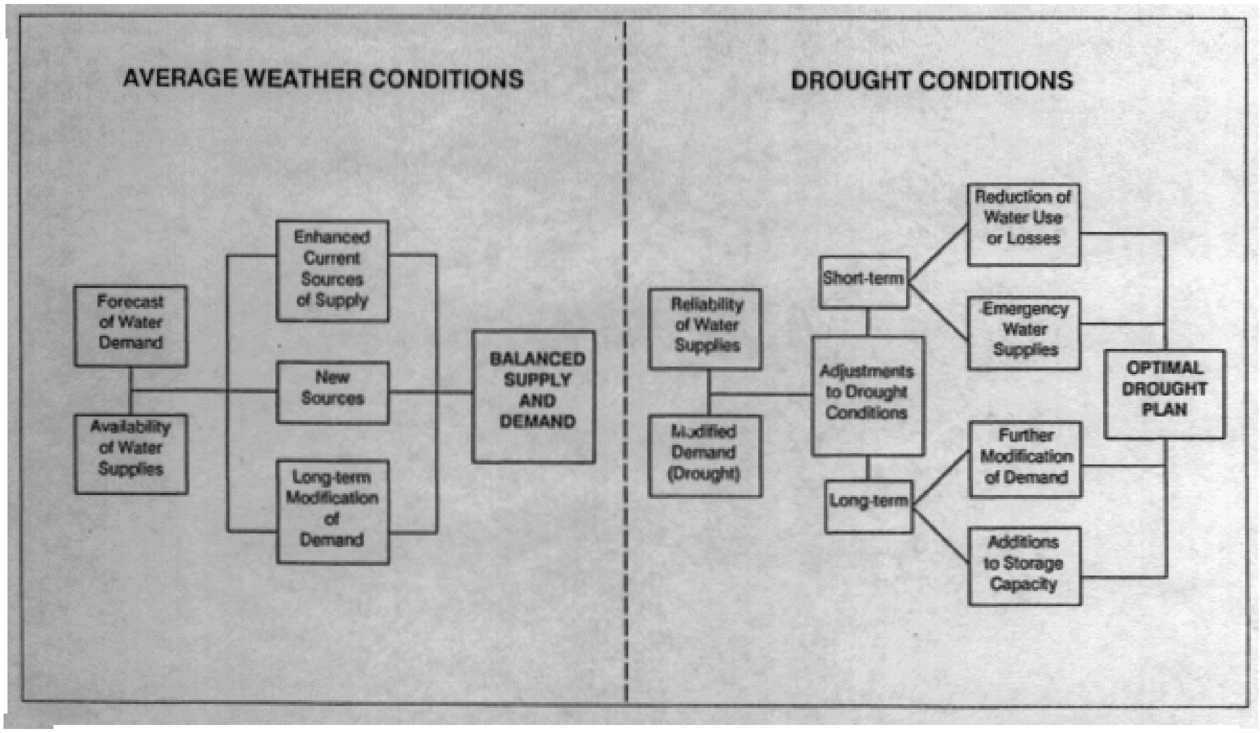
The "DROPS" Method

The DROPS (drought optimization system) method is comprised of several procedures which represent various steps in the formulation of the least-cost drought contingency plans, and a systematic evaluation of a broad range of long-term measures for drought mitigation including the provision of extra storage capacity. The model represents a conceptual framework which integrates concepts and decision criteria set forth by Russell, et al. (1970); Young, et al. (1972); and Russell (1970). A more complete elaboration of the model is given in Dziegielewski, et al. (1983a,b).

The schematic diagram presented in Figure 1 illustrates the normal progression of planning steps in developing a water supply/conservation plan. A convenient way of separating these activities is to view the adequacy of the plan in terms of normal operating conditions (e.g., average weather) and then in terms of the reliability of supply and demand management during drought emergencies.

The minimum-cost drought contingency plans are identified based on (1) the appraisal of the risk of water shortage (i.e., probability and size of water supply deficits) for the system under study during the planning period; (2) the availability and costs of emergency water supplies; and (3) the effectiveness and costs of short-term demand management (or water conservation) measures. The individual short-term drought management options are ranked

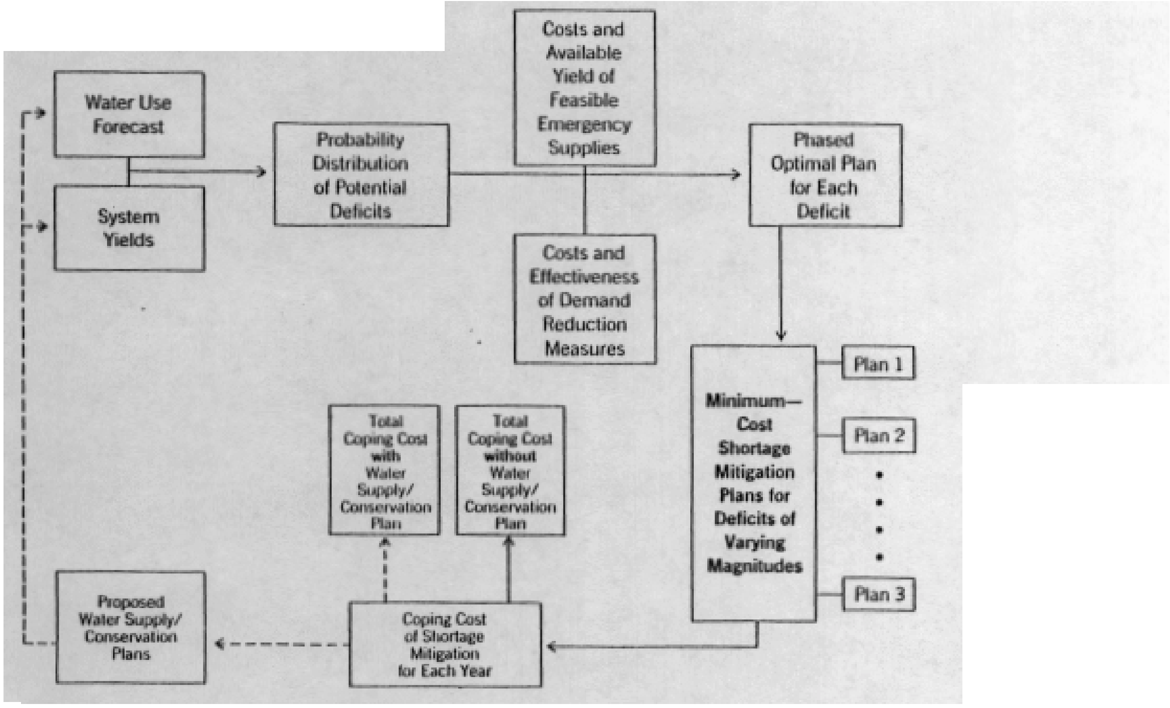
Figure 1. Development of an Optimal Drought Plan



According to their cost effectiveness in order to facilitate formulation of “phased” drought contingency programs. The long-term plan for dealing with droughts is found by balancing the incremental cost of the long-term adjustments to drought (i.e., the additions to source capacity or permanent modification of demand through nonemergency conservation programs) with the “risk-adjusted” cost of coping with drought emergencies by implementing phased drought contingency plans.

Figure 2 displays a schematic diagram of the individual steps of the model which allow the water planner to formulate and assess various plans for shortage mitigation. A procedure for determining the probability and size of water supply deficits involves estimation of current and future levels of water use with the IWR-MAIN system (Dziegielewski, 1987) and comparing them with the probability distribution of various yields of the water supply system under study obtained through the “nonsequential mass diagram analysis” proposed by Stall and Neil (1963). In order to cope with these potential deficits a number of short-term measures may be applied. The demand reduction measures and some improvements of system’s efficiency are evaluated in order to select those methods which are applicable, technically feasible and socially acceptable and to estimate the quantity of water saved and the total cost associated with each measure. A similar process is used to identify and evaluate possible emergency water supplies. The “best” packages of emergency measures are selected from the feasible alternatives using a mixed integer programming model described in Dziegielewski and Crews (1986). The individual demand reduction measures are represented by integer variables while continuous variables are used to denote the quantity of water from emergency sources. The objective function is formulated as to minimize total expenditures of an emergency response program while meeting the constraints on water availability and satisfying the existing demands for water. The resultant optimal

Figure 2. Shortage-Mitigation Plans, Formulation and Assessment



response plans, each corresponding to a different level of potential supply deficit, are examined in terms of their implementability as specific phases of a formal drought contingency plan.

The formulation of the set of minimum-cost drought contingency plans does not constitute an optimal solution to the problem of drought. Instead, iterative process is employed to compare the costs of long-term adjustments to drought (both expansion of storage and modification of demand) to the expected value of the total cost of coping with drought emergencies during the planning period.

The "optimal drought plan" is comprised of a combination of all four types of drought adjustments shown on Figure 1. Theoretically, the optimal plan (or strategy) for dealing with droughts could be determined by balancing the incremental cost of the long-term adjustments with the decrements of the cost associated with the implementation of drought contingency plans. Intuitively, one may expect that a system that has to resort to emergency measures every year or even every five years can probably deal with droughts more effectively (i.e., efficiently) by expanding the capacity of supply sources and/or implementing nonemergency water conservation programs. However, the type of economic efficiency comparisons which are used here do not have an absolute equivalence of the monetary estimates of costs. The certain costs of system expansion are compared with uncertain expenditures and economic losses associated with drought contingency plans. The latter costs are not only discounted to their present worth, but also are adjusted for the risk of drought in each year in order to obtain the expected value of annual coping cost. The final result of the DROPS model is capable of showing the tradeoff between the costs of short-term and long-term adjustments to drought. The planner or utility manager may select optimal combination of the two types of adjustments by assigning subjective weights to each of the two cost categories thus compensating for the differences in uncertainty.

The major analytical segments of the DROPS model are performed using computer programs. The efforts to perform all steps using an integrated computer system are ongoing. It is my belief that a widespread use of this or a similar procedure is likely only if the planning effort is reduced by performing all tedious tasks with the use of a personal computer and limiting the role of the water resource planner to the examination of the plausibility of initial assumptions and verification of procedures and results.

Further refinement of the drought planning framework described in this paper may considerably improve its usefulness to water resource planners. The most critical research needs are related to further development and refinement of techniques for measuring the effectiveness and costs of demand management measures. The increased availability of such techniques will permit the development of reliable data bases which, in turn, will persuade the practitioners to use these procedures in their every day planning activities. A prior evaluation of a wide range of drought management options will allow them to make more informed decisions during crisis situations and may also result in a more efficient planning for droughts in the long run.

References

Dziegielewski, B. and J.E. Crews. 1986**.** Minimizing the Cost of Coping with Droughts: Springfield, Illinois, Journal *of Water Resources Planning and Management,* ***ASCE,*** vol. 112. No.4.

Dziegielewski, B., D.D. Baumann, and J.J. Boland. 1983a. *Evaluation of Drought Management Measures for Municipal and Industrial Water Supply,* U. S. Army Engineer Institute for Water Resources, Report 83-C-3.

----. 1983 b. *Prototypal Application of a Drought Management Optimization Procedure to an Urban Water Supply System,* U.S. Army Corps of Engineers, Institute for Water Resources, Report 83-C-4.

Dziegiclewski, B. 1987. *The IWR-MAIN Disaggregate Water Use Model.* IN: Universities Participation in the Water Resources Regulation and Management Processes. Proceedings of the 1987 Annual Meeting of the Universities Council on Water Resources, Inc.

Russell, C.S.,1979. *Water Deficit Planning,* Southeast Regional Conference on Water Conservation and Alternative Water Supplies, Georgia Institute of Technology, pp. 209-219.

Russell, C.S., D.G. Arey, and R.W. Kates. 1970. *Drought and Water Supply,* Johns Hopkins University Press, Baltimore, MD.

Stall, J. B., and J. C. Neill, 1963. Calculated Risks of Impounding Reservoir Yield, *Journal of the Hydraulics Division, ASCE,*, Vol. 89. No. HYI.

Young,G. K.,R. S. Raylor,and J. J. Hanks. 1972.A *Methodology for Assessing Economic Risk of Water Supply Shortages,* U. S. Army Corps of Engineers Institute for Water Resources, Contract Report 72-4