WATER CONSERVATION ISSUES –

INTRODUCTION TO WATER SUPPLY AND CONSERVATION PLANNING

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Introduction

Many municipalities regard an adequate supply of water as an essential service to ensure public health and safety, economic growth, and community well-being. The overall goal of a water supply system is to deliver sufficient quantities of water at suitable pressures at the minimum cost for public consumption and fire protection. Also, the supply should meet the levels of quality mandated for or acceptable to the various urban uses, such as residential, commercial or industrial applications. Although individual systems may vary greatly with respect to their engineering sophistication and complexity of operation, they all deliver the same product and rely on similar treatment, storage, and distribution facilities.

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 necessary to design and build water facilities with substantial extra capacity to accommodate population growth and industrial development. In the past, 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.

Today, there are several new considerations which must be incorporated into urban water supply planning. These include:

(1) <u>Limited availability of untapped sources of supply</u>. Many urban areas, especially in the West, have begun to experience allocation problems among competing users as regional surface supplies have become fully appropriated, and groundwater acquifers become depleted. Acute or chronic source contamination, particularly among groundwater users, further limits water availability. Also, large-scale water transfers between river basins or across political boundaries are no longer feasible due to legal, political and environmental constraints.

(2) <u>Water purity standards</u>. The Safe Drinking Water Act of 1974 and its recent amendments have forced many communities to comply with increasingly stringent limits on a large number of contaminants in drinking water. This has led to a significant increase in the cost of water treatment and in some cases water sources which served communities for decades are no longer adequate because of excessive contamination.

(3) <u>Financial constraints</u>. The prospects for financing major construction programs are discouraging in many public utilities. Water supply competes for funds with other essential municipal services such as the collection and disposal of wastewater and solid waste, the supply of gas and electricity, the

provision of transportation infrastructure and welfare services. High investment requirements, and traditionally low revenues due to subsidized pricing conventions place the capital-intensive water supply at a disadvantage in that competition. Also, the possibilities for obtaining water supply from federal multipurpose projects are limited because of new cost-sharing requirements (e.g., up-front financing).

(4) Environmental concerns. New environmental legislation, including the National Environmental Policy Act (1970); the Federal Water Pollution Control Act (1972) and their Amendments (1977, 1987) have 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.

(5) Changing public attitudes. The increasing concerns 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 potential adverse environmental impacts.

These new considerations have forced water planners to extend their perspective beyond traditional supply augmentation projects. The most profound change involves the use of demand management alternatives. However, in recent years, a number of unconventional supply alternatives have also been considered. These include:

(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

(5) Increasing runoff through watershed management or cloud seeding

While structural solutions to water supply planning might have been efficient in the past, the economic, social and environmental cost of some of these unconventional supply augmentation projects have placed them beyond the reach of many water agencies. This situation 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.

New Analytical Tools

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

(3) Methods for drought planning that involve integrating capacity expansion with demand reduction projects

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 in terms of the reliability of supply and demand management during emergencies such as drought or source contamination. The new analytical tools are needed for performing evaluations of alternatives for both types of conditions. The following sections give an overview of methods pertaining to water demand forecasting, evaluation of water conservation and drought planning and management.

Water Demand Forecasting

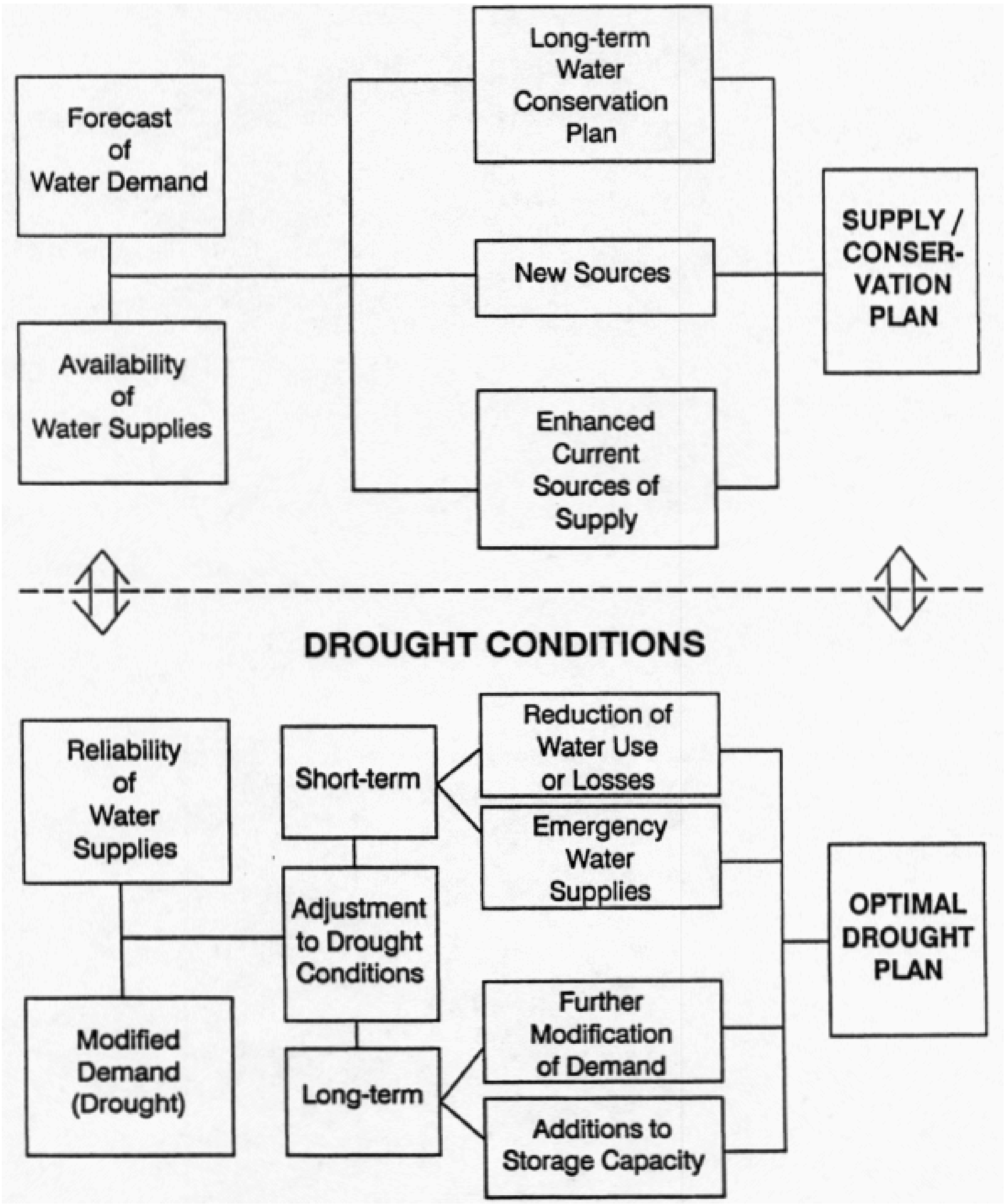
For the efficient short-term operation of water resource systems, managers require accurate forecasts of water demand. These forecasts have usually been based on previous levels of water use and have influenced the day-today operation of the supply systems. Long-term forecasts of water use are necessary for establishing sound water supply plans and for determining the effectiveness of water conservation measures. In addition, predictions of future water use are essential for planning major investments in new supply facilities, especially establishing the appropriate scale of any engineering project. Forecasting water use is a complex procedure that involves economic, environmental, and engineering considerations.

Traditionally, the most common and widely used forecasting method has been the per capita approach, whereby historical trends of water use are extrapolated to a future date (Baumann and Dworkin, 1978). Population growth is then projected for the same period and multiplied by the estimated per capita use to arrive at a predicted future water use for a particular urban area. Failure to take into account major influences on future water use in various sectors, such as changes in income, housing stock, industrial mix, and price of water, are the most critical shortcomings of this method. The per capita approach can seriously overestimate demand for water, thereby resulting in unnecessary and costly investments.

Increased scarcity of readily available, high quality water and rising costs of providing suitable supplies have brought considerable attention to improving forecasting procedures. There have been many strong proponents of disaggregated water use forecasts which take into account differences in the socioeconomic characteristics of the resident population (Baumann and Dworkin, 1978; Baumann et al., 1980; Boland et al., 1984; Grima, 1973). Studies reported in <u>An Annotated Bibliography on Techniques of Forecasting Demand for Water</u> have shown that both the level of average daily municipal use as well as its seasonal variation can be adequately explained by selected demographic, economic, and climatic characteristics of a study area (see Dziegielewski et al., 1981). Variables representing these selected characteristics are used within the IWR-MAIN System in

FIGURE 1.
PLANNING STEPS IN DEVELOPING A
WATER SUPPLY/CONSERVATION PLAN

AVERAGE WEATHER CONDITIONS



generating water use forecasts which are disaggregated by sector and season.

Among the factors which have been found to influence the demand for water, it is possible to distinguish those which determine the need for water and those which affect the intensity of water use. This distinction has important implications for forecasting water demand. Often future water use is determined based on noneconomic engineering parameters (water requirements) while ignoring the effects of price and other economic factors. Individual factors in each group depend on the type of water users. In the residential sector, factors which affect the intensity of use include: (1) income, which measures the consumer's ability to pay for water, (2) conservation behavior, which reflects the consumer's willingness to substitute inconvenience or technological innovations for water; and (3) price, which determines the amount of water a consumer is willing to pay for. For a given set of water-using appliances and activities as defined by the "need" variables, water use will increase with increasing income, and decrease with increasing conservation activity and price. Price of water, including the price charged for wastewater disposal, and conservation also affect the intensity of water use by nonresidential users. The "need" variables for these users can be defined in terms of purposes for which water is used in various types of manufacturing firms or commercial and institutional establishments. The most adequate approach to water use forecasting is one which takes account of factors which determine both the need for water as well as the intensity of water use within disaggregate groups of water users.

The Institute for Water Resources has developed a computer model designed to forecast future water demands called the IWR-MAIN (municipal And Jndustrial fleeds) Water Use Forecasting System. More than fifty years of statistical and econometric analysis has provided a large base of knowledge concerning levels and patterns of urban water use, and dependence upon a wide range of explanatory variables. Much of this knowledge has been incorporated into specific forecasting models and techniques, which are incorporated into the IWR-MAIN System. The best forecasting method strikes a balance between the demands and complexity of the planning situation and the cost and difficulty of obtaining the necessary data. Once the required data have been gathered and the initial data files established, the computer-based methods of IWR-MAIN permit fast and inexpensive data manipulation. Alternative forecasts for a range of planning assumptions can be prepared quickly using IWR-MAIN, and repeated as often as changing circumstances warrant. Long-range forecasts prepared with the IWR-MAIN System can take account of service area expansion, rate increases, changes in population characteristics (family size, etc.), employment trends, water conservation programs, or drought.

Evaluation of Water Conservation

Given some level of supply, conservation consists of reducing the use of water, reducing the loss or waste of water, or increasing the recycling of water, so that supply is conserved, or made partially available for future or alternate uses. The essence of conservation is a reduction in water use or water losses. Thus, conservation practices are those efforts that result in a level of water use at some future time which is less than the level would have been at that time had the practice not been implemented. However, not all practices that reduce water use should be considered desirable. The beneficial effects of the reduction in water use (loss) must be considered greater than the adverse effects associated with the commitment of other resources to the conservation effort. Thus, it can be said that a water management practice constitutes conservation when it meets two tests:

(1) It conserves a given supply of water through reduction in water use (or water loss)
(2) It results in a net increase in social welfare

In other words, water conservation is defined as any beneficial reduction in water use or in water loss. Water conservation measures have been classified into three broad groups (Baumann et a!., 1980):

(1) Regulatory measures
(2) Management practices
(3) Education efforts

The regulatory measures are those practices or measures that are dictated by local, state, or Federal legislation. In general, these measures would likely carry penalties or sanctions for noncompliance, e.g., local requirements of low-flush toilets in new dwelling units (see Table 1).

Management practices are those implemented by local water utility or by the responsible units of government that result in a beneficial reduction in water use or water losses. These include measures such as leak detection, metering, or modification of pricing policies (see Table 1).

Educational campaigns are directed toward voluntary beneficial reductions in water use or losses. For example, information on conservation efficiency in lawn sprinkling may result in a reduction of lawn water use without damage to lawns (see Table 1).

<u>Conservation Effectiveness</u>. Based upon a review of the literature up to 1982, the major conclusion about estimates of effectiveness of water conservation measures is that little is known (Boland et al., 1982). An exception is a recent study for the U.S. Department of Housing and Urban Development (1984) which provides the most recent and best available estimates on water saving devices.

It is not uncommon to read about enormous reductions in water use for a specific community attributed to conservation. A combination conservation device retrofit program/rationing program implemented in Marin County, California during the 1976-77 drought resulted in a 37 percent reduction in net water demand (Brown and Caldwell, 1984). However, the estimates of reduced water use during a crisis are drastically different from those during normal times. There is an enormous variation in estimates of effectiveness on water saving devices, up to 300 percent (Maddaus, 1987).

There are three major reasons for the variation in estimates of the effects of specific water saving strategies. First, many estimates are applicable only for the conditions at the sites from which they were derived. Second, the studies to estimate effectiveness may be poorly designed, leading to erroneous conclusions. Third, many estimates are based on a priori reasoning with no empirical data.

Clearly, during a prolonged drought residents are more likely to employ water reducing devices than during average or wet years; hence, estimates on effectiveness of measures implemented during drought cannot be assumed to be applicable during nondrought years. However, most of the estimates of effectiveness have been derived during periods of drought. This was particularly true concerning the California drought of the 1970s. In addition to drought, average weather (climate) varies from place to place and is an important determinant of water use and therefore of the effectiveness of water conservation measures. Similarly, the socioeconomic conditions within each community which influence the effectiveness of water conservation vary markedly. Is the community primarily residential or is there significant industrial and commercial water use? What is the price of water? What is the income of the customers? What is the lawn size of the residential customers? In order to calculate more precise estimates of water use reduction, community water use must be disaggregated and relevant information on the characteristics of each user class must be obtained to derive more precise estimates of effectiveness.

One common error is that many studies estimate the effectiveness of a specific conservation program by a before-and-after study design. Water use is simply compared before the implementation of a conservation program with water use after the program has been implemented without taking

ILLUSTRATIVE LIST OF WATER CONSERVATION MEASURES

Regulations

A. Federal State Laws and Policies
  1.Presidential Policy
  2. PL 92-500
  3.Clean Water Act Amendment 1977
  4.Safe Drinking Water Act

B. Local Codes and Ordinances
  1.Plumbing Codes for New Structures
  2.Retrofitting Resolutions
  3.Sprinkling Ordinances
  4.Changes in Landscape Design
  5.Water Recycling

C. Restrictions
  1. Rationing
    a. Fixed Allocation
    b. Variable Percentage Plan
    c. Per Capita Use
    d. Prior Use Basis
  2.Determination of Water Use Priorities
    a.Restrictions on Public and Private Recreational Uses
    b.Restrictions on Commercial and Institutional Uses
    c.Car Wash Restrictions
    d. Pool Filling Restrictions

Education

A. Direct Mail
  1. Pamphlets, Bill Inserts
  2. Newsletters, Handbooks
  3. Posters, Buttons

B. News Media
  1.Radio/TV Ads
  2. Newspaper
  3.Movies

C. Personal Contact
  1. Speaker Program
  2. Customer Assistance

D. Special Events
  1. School Programs
  2. Slogan / Poster Contests
  3. Billboards
  4. Exhibits

Management

A. Leak Detection and Repair

B. Rate Making Policies
  1. Metering
  2. Pricing Policies
    a. Marginal Price Policies
    b. Increasing Block Rate
    c. Peakload Pricing
    d. Seasonal Pricing
    e. Summer Surcharge
    f. Excess Use Charge

C. Tax Incentives and Subsidies

D. Voluntary Implementation of Water Saving Devices
  1. Toilet Inserts
  2.Pressure-reducing Valves
  3.Faucet Aerators
  4.Low Flow Showerheads
  5. Sprinkler Timers
  6. Water Efficient Dishwashers / Clothes Washers
  7. Pool Covers

into consideration the changes that occurred in the other determinants of water use—weather, income, price, employment, housing mix, etc. Finally, there is little information about the factors affecting the adoption of voluntary water conservation measures. The results of educational campaigns are usually based on poorly designed studies and/ or on communities under crisis conditions such as drought.

In water supply and conservation planning, the IWR-MAIN System can be used to estimate the effectiveness of proposed water conservation measures. The effectiveness of a measure is based on a disaggregate demand forecast and the consumer acceptance of the measure. Also, the benefits and costs of water conservation measures and policies can be identified and measured by comparing conditions expected to exist with water conservation to those without conservation. Thus water conservation measures which result in a reduction of water use with an overall net benefit may be identified based on the calculation of conservation measure effectiveness performed by the IWR-MAIN System.

Drought Contingency Planning

The advances made in water conservation and demand forecasting have all contributed to more effective drought management planning and policies. Drought management requires balancing the costs of capacity expansion against the expected damages and costs of a supply shortage. This requires the use of demand forecasting to estimate future supply deficits as well as a thorough understanding of the costs and benefits of supply augmentation. The costs of demand reduction measures and their effectiveness and benefits must also be known. In addition, a methodology to estimate expected damages resulting from the projected deficits in supply is necessary. This will permit a water manager to place a value on the reliability of the supply and to determine the optimal strategy to adopt when a shortage occurs.

In drought contingency planning, explicit consideration of water shortages and means of dealing with them may result in considerable savings in water supply investment. IWR-MAIN water use forecasts and conservation evaluation data can serve as the basis for drought planning. In order to find the best long-term strategy for balancing the economic, social, and environmental cost of providing increased capacity against the risk and cost of water supply shortage, it is necessary to determine the damages resulting from various levels of water shortage. A carefully prepared contingency plan for coping with water shortage should significantly reduce the expected cost of any deficits that would occur. Planning and Management Consultants, Ltd. has developed techniques for determining the management strategy that minimizes the sum of total economic losses, trading off the cost of additional water from various emergency sources against losses resulting from cut backs in water delivery achieved by water conservation programs. The procedure allows for adjustments in a drought management program in response to changing conditions during the course of a drought, and utilizes the water use forecast and the effectiveness of specific conservation measures as provided by the IWR-MAIN Water Use Forecasting System.

Russell et al. (1970) pioneered the geographic research in this area. Using economic data from the 1966 Massachusetts drought, they determined procedures for timing and sizing increments in the sale yield of a system to minimize expected drought losses. More recently, based on this and subsequent studies, a procedure known as the Drought Optimization Procedures (DROPS) was developed and tested for the Corps of Engineers by Dziegielewski et al., as reported in the Evaluation of Drought Management Measures for Municipal and Industrial Water Supply (1983a). This report also includes an annotated bibliography on drought contingency planning. In conjunction with this report, a prototypal application of DROPS for Springfield, Illinois was conducted to illustrate the data gathering and analysis process (Dziegielewski et al., 1983b).

DROPS uses probabilistic forecasts of supply, combined with a disaggregated forecast of demand, to determine future deficits. Compensation for any water deficit is made up from feasible supply augmentation options and demand reduction measures which best minimize economic losses. This urban water planning process given drought conditions is illustrated in Figure 2. The alternatives are either short-term or long-term adjustments to the drought conditions. Through either alternative, water conservation is an option to be considered in the development of the optimal drought plan. If a long-term response to drought is chosen, then the actions taken under the drought plan will force a new evaluation of the supply/conservation plan previously developed under average weather conditions. As with the water conservation evaluation procedures, DROPS uses both the water use forecasts of IWR-MAIN and the estimates of conservation effectiveness generated by IWR-MAIN.

Conclusions

Water conservation planning, as an integral part of urban water supply development, has captured national prominence in resource planning and management and is likely to play an important role in water resources planning in the future. It is reasonable to assume that the full implications of conservation in an engineering, economic, social, and environmental sense are not fully understood and that further research and experience will provide useful information. The Task Committee on Water Conservation of the Water Resources Planning Committee of American Society of Civil Engineers (ASCE) in 1981 noted: “[there are] many areas of water conservation in which our knowledge of technology, impact assessment, and plan evaluation is insufficient to permit rational comparison of water conservation alternatives with alternatives involving the development of new water supplies.”

These deficiencies can be eliminated to a large extent by realizing that water conservation is only a part of the broader objective of total water management and as such should be looked at through Federal planning principles described in <u>Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies (principles and Guidelines)</u>. This would significantly help resolve the problem of plan evaluation. Undoubtedly, many technical and environmental aspects of water conservation need to be further explored; however, these shortcomings are present to a comparable degree in consideration of the full range of structural as well as nonstructural alternatives.

Consequently, new techniques of planning and methods of evaluation have been developed.
Unlike the past, the goal is to determine the optimum combination of all alternatives to balance supply (including drought) and demand.

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FIGURE 2. URBAN WATER PLANNING DURING DROUGHT