## ABSTRACT

ANDREW J. LAWLER. A Survey and Assessment of Drought Contingency Plans in the Southeastern United States. (Under the direction of DAVID H. MOREAU)

Water utilities in the southeastern United States were surveyed to identify those utilities that were affected by the drought of 1986 to such an extent that their normal operations were modified and to identify utilities that have drought contingency plans. Case studies of four of these utilities were performed to examine the criteria local governments use for invoking demand and supply management techniques during droughts. Literature was reviewed to determine the available criteria and techniques used in drought management. Several utilities had to modify normal operations without the aid of drought contingency plans. Utilities often use generic ordinances with little or no technical bases to implement demand and supply management techniques. Criteria used for decision making include: engineering judgment, risk analysis, reservoir drawdown and the Palmer Drought Severity Index.

## TABLE OF CONTENTS

## ACKNOWLEDGEMENTS

I would like to thank Dr. David H. Moreau for the opportunity to work on this project and his guidance in preparation of this report. I am also grateful to Dr. Donald T. Lauria and Dr. Richard N. Andrews for their positive criticism and support during the preparation of this report.

I especially appreciate the help I received in putting together this report from the staff at the Water Resources Research Institute including Eva Tew, Linda Lambert, Frances Yeargan, Daphne Phillips, and Mary Warner Sprinkle.

I also appreciate the moral support I received from Laura Myers, Jim Garber, Dan Elliott, Kathy Dolce, my family and all my friends in Chapel Hill.

This investigation was conducted as part of a research program supported by The Water Resources Research Institute of the University of North Carolina and by the United States Geological Survey, Grant No. 14-08-0001-G1487.

## LIST OF TABLES

# LIST OF FIGURES

# INTRODUCTION

Water supply planners have always attempted to supply people with a pure, reliable source of water. However, "the day of unquestioning construction of mammoth dams, reservoirs and other water reclamation projects is over "(An Age of Economics...,1986). With the problem of droughts, increased demand and contaminated supplies, the question of will we have enough water for tomorrow is continually asked. Water utility managers must now manage their systems as well as possible to prevent severe social, economic and environmental impacts from occurring due to these problems.

Drought has been defined in many ways, all of which are correct to an extent. The impact of drought on municipal water supply and the criteria used to manage these systems under drought conditions are the subjects of this paper and lead to the definition of effective drought proposed by Warwick (1975):

> "Effective drought is the shortage of water, due to meteorological and hydraulic deviations from the climatological norm, which results in an otherwise unscheduled modification of water-supply management practices to compensate for the shortage."

This definition is chosen because individual municipalities that face the same meteorological drought conditions as other municipalities often are affected differently due to previous planning. Therefore municipalities are considered in a drought if the conditions result in some form of unscheduled motification of there normal operating procedures.

The drought of 1986 in the southeastern United States was probably the worst in at least 111 years according to the National Weather Service (Aug. 5, 1986). As shown in Figures 1.1 and 1.2 much of the Southeast was in an extreme drought situation as of August 2, 1986 based on the Palmer Drought Severity Index (DSI). Water problems in the South have traditionally involved flooding rather than drought. However, rapidly increasing populations coupled with droughts have pushed many water systems beyond their designed capacities. The problem in the South, according to Greene (1987) in his article questioning whether the crippling drought of 1986 was preventable, is that the South has traditionally been resistant to water management policies that restrict the usage of water in any way.

The drought of 1986 caught several utilities quite unprepared. The objectives of this paper are to attempt to determine the extent to which water utilities in the Southeast were affected by the drought and the extent to which they were prepared to manage demands and supplies during the drought; and to determine the criteria and techniques that utilities use for invoking demand and supply management techniques during droughts. This was done through the use of (1) a literature review; (2) a survey on the impact of the 1986 drought in the southeastern United States, and; (3) case studies of four utilities and their responses to the drought of 1986.

The first section reviews the literature related to drought management. It includes the criteria used for operating a water supply under drought conditions and risk management techniques used by utilities, and optimization techniques for reservoir operating policies.

The second section shows the results of a survey on the impact of the drought of 1986 in nine southeastern states. The questionnaire was sent to 573 water utilities that serve large to very large systems (>10,000 population). In the United States systems of this size represent only 4.7% of all water systems yet they serve over 78% of the population (Grigg, 1986). Also over 80% of U. S. residents live in cities and towns with populations over 10,000 (Grigg, 1986). The survey, therefore, represents a large portion of the population that was impacted by the drought of 1986. The survey included questions on the following: implementation of conservation; regional water agreements to buy and sell water; operating policies or ordinances; technical basis for these policies; and supply and demand. The objectives of the survey were to identify those utilities that were affected by the drought of 1986 to such an extent that their normal operations were modified; and to identify utilities that had drought contingency plans in place.

The final section contains case studies of four utilities in the northern piedmont of North Carolina. These include the City of Durham; Orange Water and Sewer Authority (OWASA); the City of Greensboro; and the City of High Point. These utilities were chosen because of their large size (>50000 population), close proximity, and the various states of their supplies and system users (i.e. residential, university, industry, commercial). This choice shows the variation in "effective drought" experienced by four cities separated by only 60 miles.

The objectives of this part of the study were to determine the state of their preparedness to handle droughts, the status of intergovernmental agreements, their decision making criteria, the characteristics of their information systems, their capacity to predict the consequences of their decisions, opportunities for regional cooperation, and their actual performance in 1986. The results of these cases are presented and conclusions and suggestions are given.

Much of the literature reviewed in this report refers to risk and risk levels. Risk is a general term used term that is defined here as the possibility or chance of some shortfall or undesirable event. The problem is that the magnitude of these shotfalls is often unclear. A risk level is the level of probabilty at which one will meet or fail to meet a desired outcome.

Water demand as used here is the reqirement of water in both quantity and time of need for the purpose of public water supply. Conservation is any beneficial reduction in water use and is separate from supply augmentation. These terms often are used differently by different authors.

Conclusions from the literature, survey and case studies are given regarding drought management policies, criteria and options available to water managers. Recommendations for future research in the field of drought management are made which should be helpful to utility directors in developing future policies.

## LITERATURE REVIEW

The literature related to the criteria used for decision making under drought conditions is limited. The literature on techniques for deriving policies is quite large but is limited in the area of drought management and single purpose water supplies. Both criteria for drought management and techniques for deriving policies are reviewed herein.

### Criteria for Drought Management Decisions

Drought policy is often left solely to local utilities, rather than state or federal governments. Wilhite (1986) did a comparative analysis of drought policies in the US and Australia; he stated that the US has reacted to drought by crisis management rather than risk management. Current policy in the US does not encourage the adoption of efficient management practicies to ensure against abnormal risk. Risk management should be a consideration in developing a drought policy at a national level.

Most optimization models are based on minimizing economic losses subject to some constraints, however, it seems utilities operate to reduce risk of some undesirable event from occurring. Some optimization models have included risk including those by Simonovic and Marino (1981) and Askew (1974a) as well as others.

Recently several utilities have adopted drought management policies that take into account the risk of not meeting a given demand, calling for conservation, running out of water or some other undesirable effect of a water shortage. The City of Durham, NC, adopted a drought management plan in 1982 developed by McCrodden and Peddock (1982) of Research Triangle Institute.

A set of risk tables are developed for each month of the year based on the previous month's streamflow and the current water level. Streamflow is used to predict inflow in future months, while water level represents current storage. The tables give the probability of not sustaining a given demand throughout the remainder of the drawdown-refill cycle (April-March). The benefits of these tables are that they are designed for ease-of-use by the utility director. The utility can choose a risk level it is willing to face and then decide if they need to impose water use restrictions or supplement supply, in order to reduce their risk of not sustaining current demand. The problem with this approach is that the magnitude of economic and social impacts of not meeting a given yield is not considered.

The Washington Metropolitan Area, consisting of over 3 million people, is served by three main water supply agencies. After 20 years, a successful regional water supply plan was developed including a drought contingency plan (McGarry, 1985). A drought management plan with three stages was developed. Table 2.1 shows the percent probability they feel acceptable for implementing water use restictions of a given duration. For example, 8 years out of 100 they feel it is acceptable to implement restrictions on outdoor water use for a period of less than 30 days. By choosing these risk levels required storage was reduced by one third for the year 2000. "Political officials are the ones who must defend the chosen risk and take the heat if the public does not like these restrictions when they are imposed" (McGarry, 1985).

Table 2.1 - From McGarry, 1985

% Probability of Occurrence in any Year Considered Acceptable

| Stage | Period of Implementation <30 Days | >30 Days |
|---|---|---|
| I-Restricting Outside Use | 8% | 5% |
| II-Air Conditioning & Swimming Pool Restrictions | 3% | 2% |
| III-A Increasing Severity | 1% | 1% |
| III-B " " | 1% | 1% |
| III-C " " | 1% | 1% |

The Orange Water and Sewer Authority (OWASA) has currently adopted a drought management plan developed by Moreau (1987, 1988A, 1988B) that is based on the concepts of risk management. Policies have also been developed for the City of Durham (Moreau 1988A, 1988B) and the City of Greensboro (Moreau 1988B).

These policies take the approach of risk management and deal specifically with existing supplies during periods of drought. Moreau's model is based on the uncertainty of future inflows and the risk (probability) of reaching (avoiding) some undesirable level such as running out of water, entering conservation or purchasing water to avoid the other consequences. "Action levels are chosen to satisfy acceptable risks of meeting (or failing to meet) various targets for system performance." (Moreau, 1988B) The general structure of this model is shown in Fig. 2.1. As an example Moreau (1988b) states that probability of occurence of imposing any form of restrictions over the remainder of the year should be held to 5% of less.

Table 2.2

| Criteria | Probability of Occurrence |
|---|---|
| Drawdown of active storage to empty over remainder of drawdown-refill cycle | .01 or less |
| Imposing mandatory conservation for more than four weeks | .05 or less |
| Imposing any form of conservation over the remainder of the year | .05 or less |

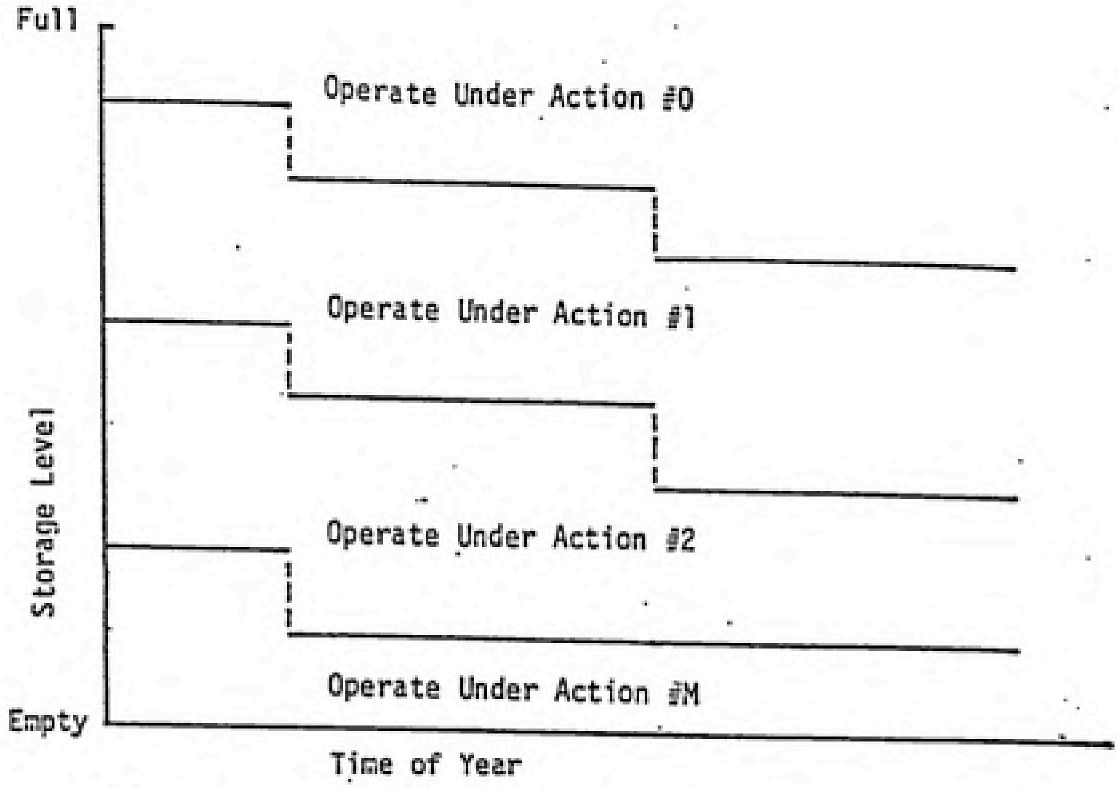



Figure 2.1 General Structure of Operating Policy

Source: Moreau (1988b)

One drawback of Moreau's model is that it does not explicitly consider the economic consequences of decisions. The judgement about what consumers are willing to pay to avoid the consequences of a drought at a given risk is left to public officials.

Positive aspects of this model are that it was developed in consultation with utility directors. It was developed for ease-of-use by utility directors and allows some freedom in choosing desirable levels of risk. Decisions about management of supply and demand can be made early in the drawdown-refill cycle rather than waiting until a point where decisions are made too late. OWASA is presently using this model and has requested to purchase water as early as July 6, 1988 (Lucas, 1988). This represents a change from past years when OWASA did not request purchases until after they implemented conservation measures.

Prior to using Moreau's model, OWASA had a drought management plan developed by Blum (1977). Blum (1977) selected lake levels for the months July through December at which different levels of conservation, purchasing or rationing should be entered. These levels were based on historical records of what University Lake levels would have been at 1977 unrestricted demand. He does not mention if these levels were based on any specific probability of not meeting demand or running the reservoir empty over the remainder of the drawdown-refill cycle. Blum also recommended that water not be purchased until stage 4 (stringent mandatory restrictions) was entered. This is turning down a viable alternative source which could help get through a drought without the social, economic and political impacts of mandatory conservation.

Several utilities in South Carolina and elsewhere use the Palmer Drought Severity Index (DSI) as a basis for decision making during droughts. The DSI as explained by Denny and Heddinghaus (1987) is an index of meteorological drought and indicates prolonged abnormal conditions affecting water-sensitive economics. The DSI is a useful index in determining the availability of supplies, reservoir levels, range conditions, amount of stock water and potential intensity of forest fires. It is useful in determining drought conditions on a regional basis but does not apply specifically to an individual water supply and their demand for water.

Several standard texts in the field of water resources engineering and planning were reviewed, but few provided any guidance in the area of drought management. Those that provided no guidance include Ameen (1964), Linsley and Franzini (1972), Clark, Viessman and Hammer (1977), and Mather (1984).

One of the few standard references that provides any guidance as to when conservation should be initiated is found in Fair, Geyer and Okun (1971, p.78). They argue that conservation must be initiated "...well in advance of anticipated exhaustion of the supply." Furthermore, they state that the decision to invoke conservation should be based on the frequency with which conservation will occur and the storage level at which it will be implemented. They suggest that in practice that level is between 20 and 50% of storage capacity, and a reasonable policy is one that requires a 25% reserve for a drought that occurs once in 20 years.

Viessman and Wetty (1985) speak of the reliability of a water supply. They argue that the risk of not meeting a given demand should be low for municipal and industrial suppliers and higher when water is used for irrigation. While they mention operating rules for reservoirs they do not give any specific criteria for operating the supply during a drought.

**Techniques For Deriving Operating Policies**

A substantial review of approximately 200 papers and reports on reservoir management and operations models was published by Yeh in 1985. Yeh notes that there have been many successful applications of optimization techniques in reservoir studies, mainly for planning purposes. Presently, however, there is still a gap between theory and application when it comes to real time reservoir operation. An important conclusion that he comes to is that many water utility directors are reluctant to use optimization models for the daily operation of their water system. Yeh gives three possible reasons for this. The first is that few system operators are involved with the development of the model. This causes them to be uncomfortable with its use and with the decisions the model suggests. A second reason is that many of the models are based on overly simplified reservoir systems, yet they are not designed for ease of use by water managers. A final reason is that many times we run into institutional constraints on use not reflected in models.

The methods reviewed by Yeh are optimization and performance criteria based simulation. Several of these models and others are mentioned in this report.

Much of the literature considers multipurpose, multiple reservoir systems rather than systems used primarily for public water supply. This paper is concerned with operations of public water supply systems during droughts.

**Optimization**

Linear Programming Models

Most linear programming models are concerned with minimizing economic losses or maximizing benefits subject to some constraint, by choosing some decision variables such as target releases and storage values.

Dorfman (1962) first demonstrated the use of linear programming on 3 over-simplified applications. Although these could not be used in real-time operation, they serve as a useful starting point for more elaborate analysis.

Meier and Beighter (1967) introduced an optimization technique for branched multistage systems and they indicate dynamic programming has a place in the practical optimization of entire river basin developments. Their model is limited though because it does not consider temporal allocations over seasons. Roefs and Bodin (1970) suggested decomposing parallel subsystems over time. The authors were unable to complete an implicit stochastic analysis process for their system and ran into computational problems for their system of 3 reservoirs.

The models reviewed to this point are deterministic in nature. Deterministic procedures may not consider uncertainties of some parameters, and may not lead to optimal or even satisfactory results. The following models are stochastic in nature.

Loucks and Falkson (1970) reviewed 3 stochastic techniques: LP, DP, and policy iteration. The LP techniques included first-order Markov chains. The three were compared using a simplified numerical example. Houck and Cohen (1978) assumed a lag-one Markov process for streamflow description. The approximate solution to a nonlinear program is found by solving two linear programs sequentially. System-wide performance levels are measured and the operation of each reservoir is coordinated with all other reservoirs.

Chance-constrained LP is one that reflects the probability conditions on constraints. Revelle, Joeres and Kirby (1969) made the first application of chance-constrained LP to reservoir system optimization. Revelle, et al. (1969) proposed the first linear decision rule (LDR) for his reservoir design and operation policy. It reads: $R_t = S_{t-1} - b_t$

where $R_t$ = release during time period t

$S_{t-1}$ = storage at end of time period t-1

$b_t$ = decision parameter to be determined.

Revelle et al. (1969) formulated problems in both the deterministic and stochastic environment. Advantages include the linear decision rule is simple to apply in practice and optimization problems are of small size, so computer solutions are not burdensome. Another advantage is that it showed optimal reservoir capacity is a function of operating policy. The most important advantage of Revelle's model is that risk is explicit. The designer or operator specifies the level of certainty involved.

Revelle and Kirby (1970) improved their original model to include evaporation losses. They also included several reservoir performance measures as objective functions including expected and reliable values of storages and releases, deviations from targets, and reliabilities of achieving stated goals.

Gustman and Revelle (1973) studied the effects of the length of decision period using the LDR. The results showed increased capacity for when decision periods were increased.

Revelle and Gundelach (1975) applied a new LDR to incorporate the stochastic nature of inflows. A problem was solved using both the new LDR and the original LDR. The new LDR showed a 16.3% increase in reservoir capacity, but decreased variance of average release by 23%. Which method should be used would depend on a benefit-cost analysis of the two alternatives. Gundelach and Revelle (1975) derived an algorithm to determine the capacity and decision constants for any reservoir operated by use of th LDR. A major advantage is that the algorithm may be easily implemented without use of a computer.

Takeuchi and Moreau (1974) used LP with stochastic DP. The objective function of this model consists of two parts: immediate economic losses within the month and the expected present value of future losses as a function of end-of-month storage levels in reservoirs. The latter function is estimated by imbedding the linear programming problem in a stochastic DP problem. An approximate solution was obtained to give an efficient operating policy. However, it cannot be stated that this is a truly optimal solution.

Houck and Datta (1981) compared multiple LDR, conditioned upon streamflows in other seasons, to the original single LDR model (Revelle et al. 1969). The multiple model returned smaller reservoir capacities than the single LDR model. When operating rules of the two models were tested by simulation of actual reservoir operation, the multiple LDR model was shown to be superior.

Randall, Houck and Wright (1986), used a linear programming model to simulate operation of the Indianapolis water system during periods of drought. Four objectives were considered. They include: maximize net revenue, maximize reliability, maximize storage at the end of the optimization horizon, and maximize streamflow. These, however, are conflicting objectives. Simulation of real time operation showed several drawbacks in this model. The operating horizon of the real-time model is shorter than the actual dought. Reliability could not be optimized when the entire drought was simulated and therfore was included as restraint. Randall et al. notes: "one of the difficulties with real-time simulation is that lack of foresight into the distant future allows the storage to be drawn down to a very low level." They also state that "meaningful trade-off curves cannot be drawn from the real-time simulation because changes in operating policies are necessary as a result of lack of foresight.

Labadie, Bode and Pineda (1986) used a network optimization model for the Fort Collins, CO, water supply. They claim the model to be useful for long-range water supply development planning; multiseason water management and drought contingency; within season operations; and future extension to daily real-time use. The model contains drawbacks; e.g. it does not account for uncertainty of future flows. It also shorts demands with a lower priority as shortages occur rather than incorporate demand management techniques, such as conservation, or supply augmentation techniques such as purchasing if available.

Simonovic and Marino (1981) used risk-loss functions associated with flood risk and drought risk in their reliability programming approach. They were able to relate reliability levels and losses caused by excess or too little storage at any given time.

Strycharczyk and Stedinger (1987) evaluated "Reliability Programming" (RP) models that used chance-constrained LP but did not use LDR's. They showed several drawbacks to this approach. "The reliabilities of minimum and maximum storage targets do not relate to the frequency with which minimum and maximum release bounds (causing 'droughts' and 'floods') would be violated. When these models were compared with Revelle _et al_. LDR and the simple standard operating procedure, the RP models constraint led to an overestimation of reservoir capacity by up to an order of magnitude.

Dynamic Programming (DP) Models

Dynamic Programming (DP) and its variations are used to optimize a multistage decision process. Several authors have taken this approach to reservoir management.

Many stochastic DP models have been developed to derive optimum operating policies that maximize the expected net dollar benefits for a water resource system. Askew (1974a) developed a procedure using DP and simulation to derive optimal operating policies that maximize net economic benefits, yet do not violate constraints on the probability of system failure. If a system were to fail, it is penalized thus inducing changes in the previous optimal policy derived. Askew (1974b) develops a chance-constrained DP that takes the noneconomic aversion to failure into account. The importance of this model is that it takes into effect the sociopolitical implications that may far outweight losses in economic benefits.

Opricovic and Djordevic (1976) used DP to optimize operation of a multi-objective reservoir with direct and indirect users. A three-level algorithm was developed as follows: first level, optimize water distribution among time intervals; second level, allocate water to direct users; third level, allocate water to indirect users (from direct users. DP is used at all levels to determine probabilities of optimal storage level during each month in the long term.

Yeh and Becker (1982) used a modified linear programming and dynamic programming algorithm for optimization of a multipurpose, multireservoir system. They concluded that this method was practical for real-time use and could be beneficial for use during periods of high streamflow or drought.

Karanouz and Mock (1987) compared a deterministic model (DPR) consisting of three components: a dynamic program, a regression analysis and a simulation; and a stochastic DP (SDP) using a discrete lag-one Markov process. They found the SDP model performed better for small reservoirs (capacity - 20% of mean annual flow). The DPR model performed better in all cases when capacity exceeded 50% of mean annual flow.

Yeh (1985) found that nonlinear programming (NLP) models work but are limited by rate of convergence and computer requirements. Presently, NLP is limited by dimensionality problems which could be solved in the future by better computers.

Simulation models have been found effective and useful in studying operation of water resource systems (Yeh, 1985). These models are able to incorporate experience of engineers, operators or planners and can therefore be very useful to a utility manager in seeing the results of his decisions before they actually occur.

A large number of optimization models exist, however, very few of these are useful for single purpose water supplies. No guidance is given on acceptable risk levels from empirical studies.

## RESULTS OF DROUGHT SURVEY

Extensive portions of the southeastern United States experienced severe drought conditions throughout the first 10 months of 1986. Lack of precipitation caused stream flows in this region to fall well below normal as shown in Figures 3.1a-g. The coastal states of Virginia, North Carolina, South Carolina, and Georgia were especially hard hit by the drought.

Although that drought had effects on a broad range of activities, the focus of this study is limited to public water supplies. To determine its impact on supplies and how local utilities managed the drought, a survey was sent to 573 utilities throughout the states of Alabama, Florida, Georgia, Kentucky, Mississippi, North Carolina, South Carolina, Tennessee, and Virginia that serve 10,000 or more people. A total of 422 utilities responded to the survey for a 74% response rate. The questionnaire is shown in Appendix A.1; responses are tabulated in tabl 3.1-3.4 and shown graphically in Figures 3.2-3.6.

The objective of the first round of the survey was to identify which utilities were affected by the drought of 1986 and what was their general state of preparedness. A more detailed survey will follow on those utilities that had drought management plans. The second survey will be based partially on the case studies of the following chapter.

Results were cross tabulated to see how different systems were affected. Systems were divided into those whose source is either groundwater or surface water. Results were also calculated individually for each state.

# STREAMFLOW DURING JANUARY–JULY 1986

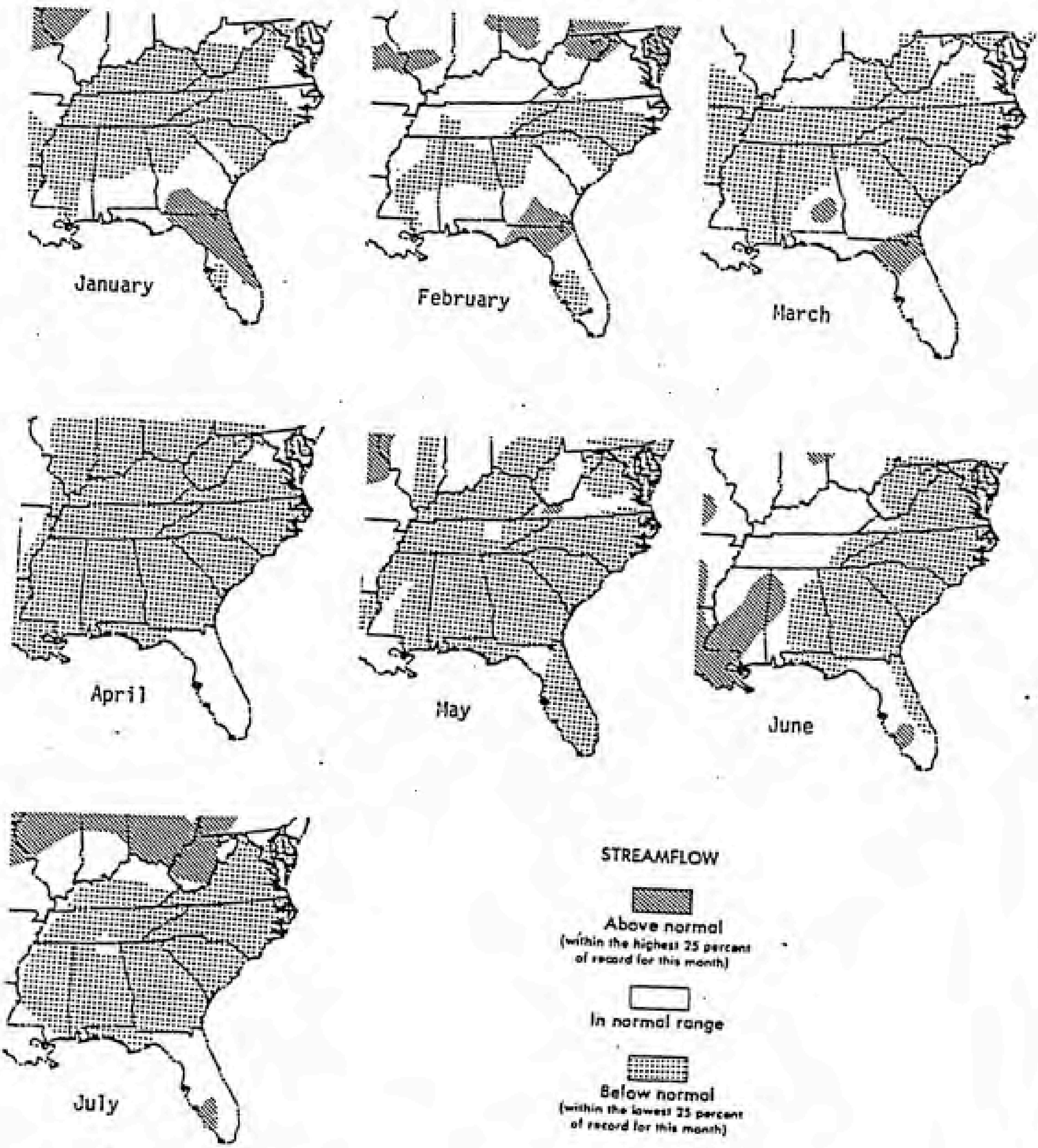



Figure 3.1 Streamflows in the Southeast: January - July 1986.
Source: National Weather Summary, US Geological Survey

Table 3.1

RESULTS OF DROUGHT SURVEY
Affirmative Responses by State

| State | Requested Water use Reduction | Voluntary Reduction | Mandatory Restrictions | Regional Agreement | Purchase Water in 1986 | Sold Water in 1986 | Drought Ordinance in 1986 | Invoke Ordinance in 1986 | Developed Policy Since '86 | Technical Report for Policy | Total Responses |
|---|---|---|---|---|---|---|---|---|---|---|---|
| AL | 15 | 15 | 2 | 16 | 5 | 13 | 9 | 2 | 6 | 2 | 42 |
| FL | 45 | 42 | 19 | 36 | 5 | 7 | 59 | 22 | 10 | 24 | 97 |
| GA | 35 | 30 | 24 | 16 | 9 | 11 | 32 | 20 | 18 | 22 | 49 |
| KY | 6 | 6 | 1 | 7 | 2 | 6 | 8 | 1 | 2 | 4 | 32 |
| MS | 1 | 1 | 0 | 1 | 0 | 0 | 2 | 0 | 1 | 0 | 19 |
| NC | 22 | 21 | 6 | 16 | 3 | 10 | 20 | 9 | 9 | 7 | 56 |
| SC | 23 | 20 | 5 | 16 | 3 | 7 | 11 | 4 | 25 | 11 | 39 |
| TN | 14 | 14 | 1 | 22 | 7 | 20 | 9 | 1 | 4 | 2 | 53 |
| VA | 9 | 8 | 2 | 11 | 2 | 12 | 14 | 5 | 3 | 4 | 35 |
| Total | 170 | 157 | 60 | 141 | 36 | 86 | 164 | 64 | 78 | 76 | 422 |

Table 3.2

RESULTS OF DROUGHT SURVEY
Affirmative Responses by State
% Total

| State | Requested Water use Reduction | Voluntary Reduction | Mandatory Restrictions | Regional Agreement | Purchase Water in 1986 | Sold Water in 1986 | Drought Ordinance in 1986 | Invoke Ordinance in 1986 | Developed Policy Since '86 | Technical Report for Policy | Total Responses |
|---|---|---|---|---|---|---|---|---|---|---|---|
| AL | 3.55 | 3.55 | 0.47 | 3.79 | 1.18 | 3.08 | 2.13 | 0.47 | 1.42 | 0.47 | 9.95 |
| FL | 10.66 | 9.95 | 4.50 | 8.53 | 1.18 | 1.66 | 13.98 | 5.21 | 2.37 | 5.69 | 22.99 |
| GA | 8.29 | 7.11 | 5.69 | 3.79 | 2.13 | 2.61 | 7.58 | 4.74 | 4.27 | 5.21 | 11.61 |
| KY | 1.42 | 1.42 | 0.24 | 1.66 | 0.47 | 1.42 | 1.90 | 0.24 | 0.47 | 0.95 | 7.58 |
| MS | 0.24 | 0.24 | 0.00 | 0.24 | 0.00 | 0.00 | 0.47 | 0.00 | 0.24 | 0.00 | 4.50 |
| NC | 5.21 | 4.98 | 1.42 | 3.79 | 0.71 | 2.37 | 4.74 | 2.13 | 2.13 | 1.66 | 13.27 |
| SC | 5.45 | 4.74 | 1.18 | 3.79 | 0.71 | 1.66 | 2.61 | 0.95 | 5.92 | 2.61 | 9.24 |
| TN | 3.32 | 3.32 | 0.24 | 5.21 | 1.66 | 4.74 | 2.13 | 0.24 | 0.95 | 0.47 | 12.56 |
| VA | 2.13 | 1.90 | 0.47 | 2.61 | 0.47 | 2.84 | 3.32 | 1.18 | 0.71 | 0.95 | 8.29 |
| Total | 40.28 | 37.20 | 14.22 | 33.41 | 8.53 | 20.38 | 38.86 | 15.17 | 18.48 | 18.01 | 100.00 |

Table 3.3

RESULTS OF DROUGHT SURVEY
Affirmative Responses by State
% of State Respondents

| State | Requested Water use Reduction | Voluntary Reduction | Mandatory Restrictions | Regional Agreement | Purchase Water in 1986 | Sold Water in 1986 | Drought Ordinance in 1986 | Invoke Ordinance in 1986 | Developed Policy Since '86 | Technical Report for Policy | Total Responses |
|---|---|---|---|---|---|---|---|---|---|---|---|
| AL | 35.71 | 35.71 | 4.76 | 38.10 | 11.90 | 30.95 | 21.43 | 4.76 | 14.29 | 4.76 | 100.00 |
| FL | 46.39 | 43.30 | 19.59 | 37.11 | 5.15 | 7.22 | 60.82 | 22.68 | 10.31 | 24.74 | 100.00 |
| GA | 71.43 | 61.22 | 40.98 | 32.65 | 18.37 | 22.45 | 65.31 | 40.82 | 36.73 | 44.90 | 100.00 |
| KY | 18.75 | 18.75 | 3.13 | 21.88 | 6.25 | 18.75 | 25.00 | 3.13 | 6.25 | 12.50 | 100.00 |
| MS | 5.26 | 5.26 | 0.00 | 5.26 | 0.00 | 0.00 | 10.53 | 0.00 | 5.26 | 0.00 | 100.00 |
| NC | 39.29 | 37.50 | 10.71 | 28.57 | 5.36 | 17.86 | 35.71 | 16.07 | 16.07 | 12.50 | 100.00 |
| SC | 58.97 | 51.28 | 12.82 | 41.03 | 7.69 | 17.95 | 28.21 | 10.26 | 64.10 | 28.21 | 100.00 |
| TN | 26.42 | 26.42 | 1.89 | 41.51 | 13.21 | 37.74 | 16.98 | 1.89 | 7.55 | 3.77 | 100.00 |
| VA | 25.71 | 22.86 | 5.71 | 31.43 | 5.71 | 34.29 | 40.00 | 14.29 | 8.57 | 11.43 | 100.00 |
| Total | 40.28 | 37.20 | 14.22 | 33.41 | 8.53 | 20.38 | 38.86 | 15.17 | 18.48 | 18.01 | 100.00 |

Table 3.4

RESULTS OF DROUGHT SURVEY
SOURCE OF ASSISTANCE IN PREPARING POLICY

| State | UTILITY STAFF | NEIGHBORING UTILITY | CONSULTANT | STATE GOVERNMENT | UNIVERSITY | LEAGUE OF MUNICIPALITIES | OTHERS | TOTAL |
|---|---|---|---|---|---|---|---|---|
| AL | 13 | 4 | 4 | 4 | 1 | 2 | 1 | 15 |
| FL | 52 | 15 | 15 | 25 | 1 | 5 | 14 | 69 |
| GA | 42 | 11 | 20 | 9 | 0 | 1 | 0 | 49 |
| KY | 10 | 2 | 1 | 4 | 0 | 0 | 0 | 10 |
| MS | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 3 |
| NC | 25 | 13 | 6 | 4 | 2 | 1 | 1 | 27 |
| SC | 18 | 7 | 3 | 23 | 0 | 2 | 4 | 36 |
| TN | 11 | 1 | 6 | 2 | 0 | 2 | 4 | 13 |
| VA | 15 | 4 | 1 | 3 | 0 | 2 | 1 | 17 |
| Total | 190 | 57 | 56 | 74 | 4 | 14 | 23 | 226 |
| of Total | 84% | 25% | 25% | 33% | 2% | 6% | 10% | 100% |

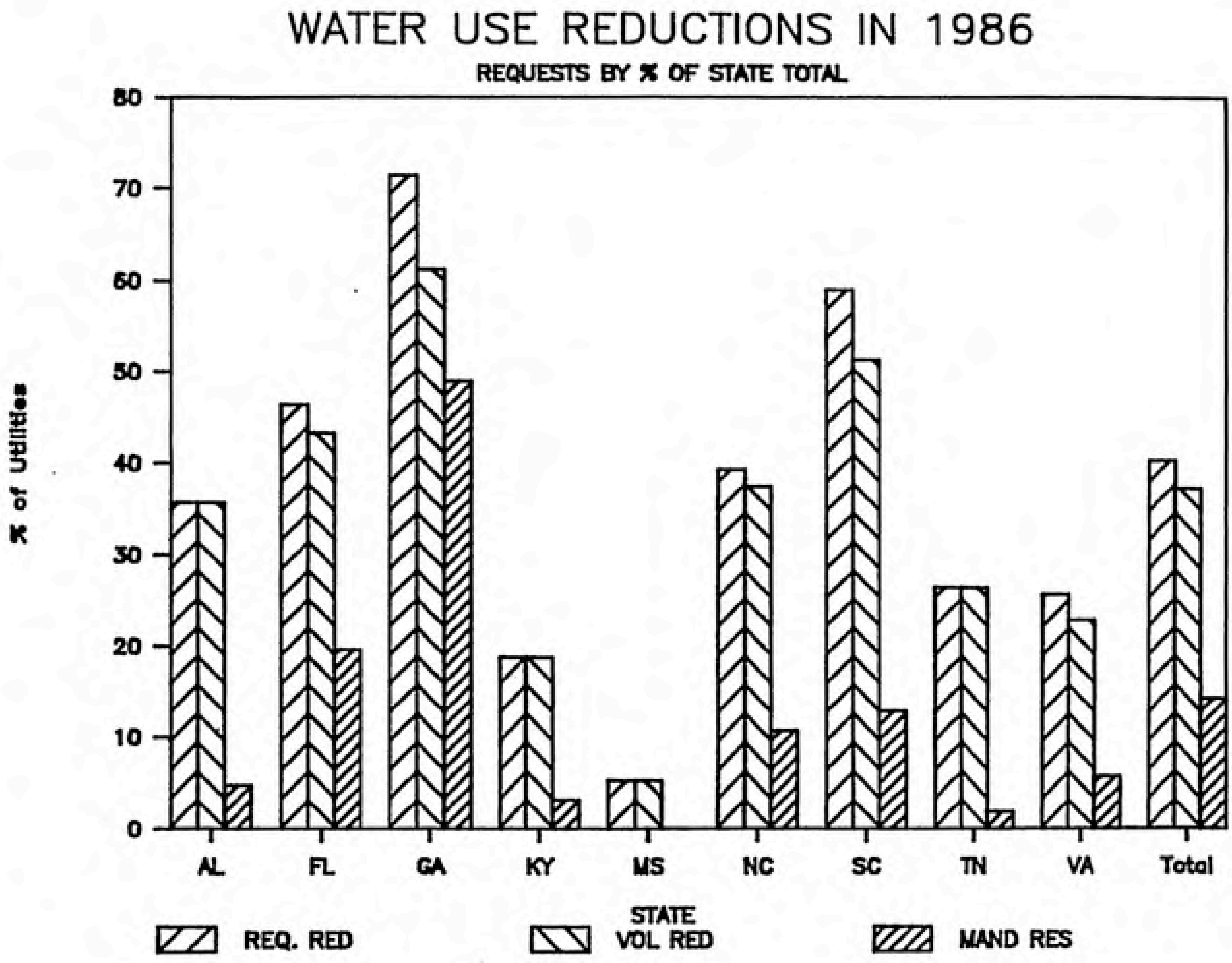

WATER USE REDUCTIONS IN 1986
REQUESTS BY % OF STATE TOTAL
% of Utilities
80
70
60
50
40
30
20
10
0
AL
FL
GA
KY
MS
NC
SC
TN
VA
Total
STATE
REQ. RED
VOL RED
MAND RES

Figure 3.2

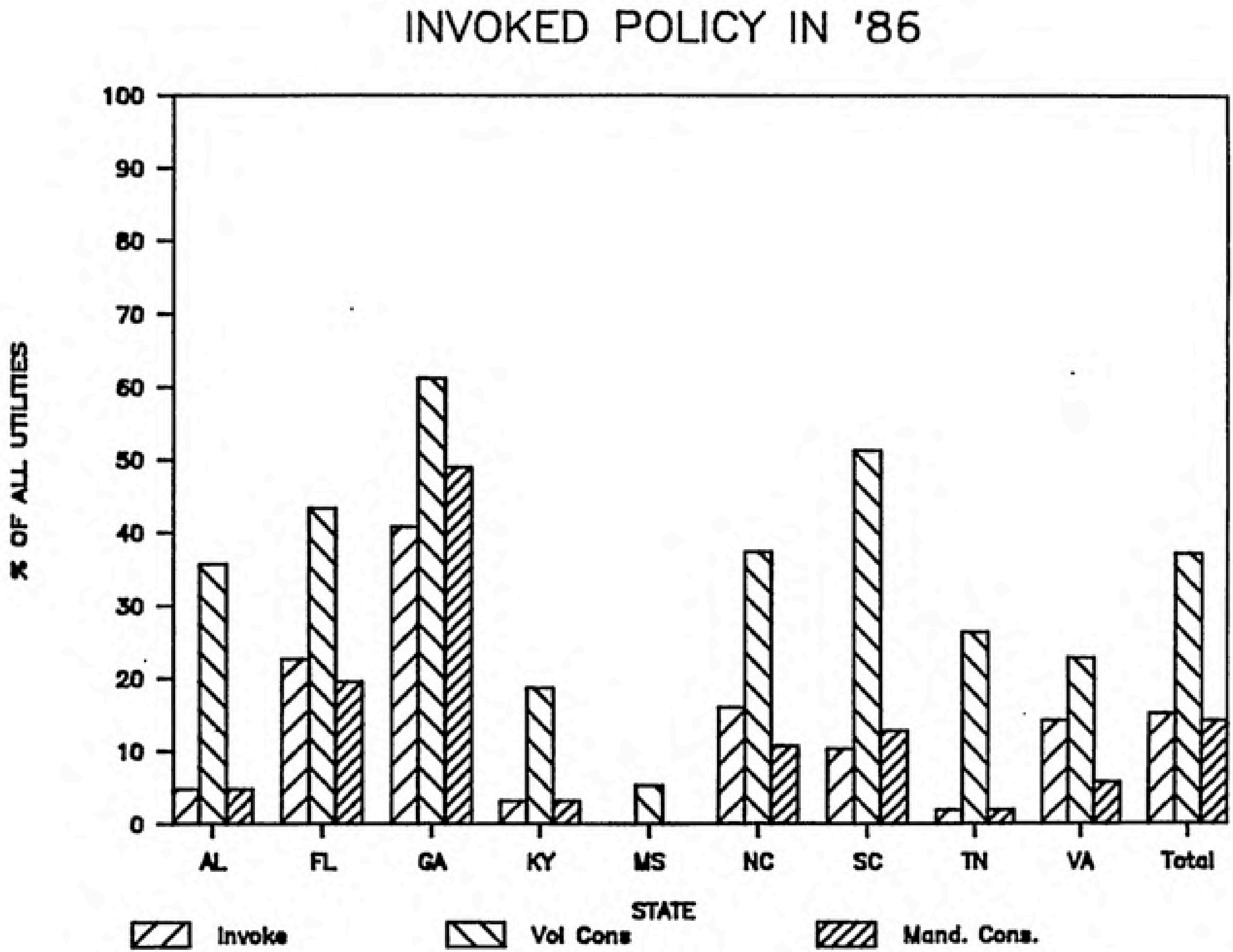
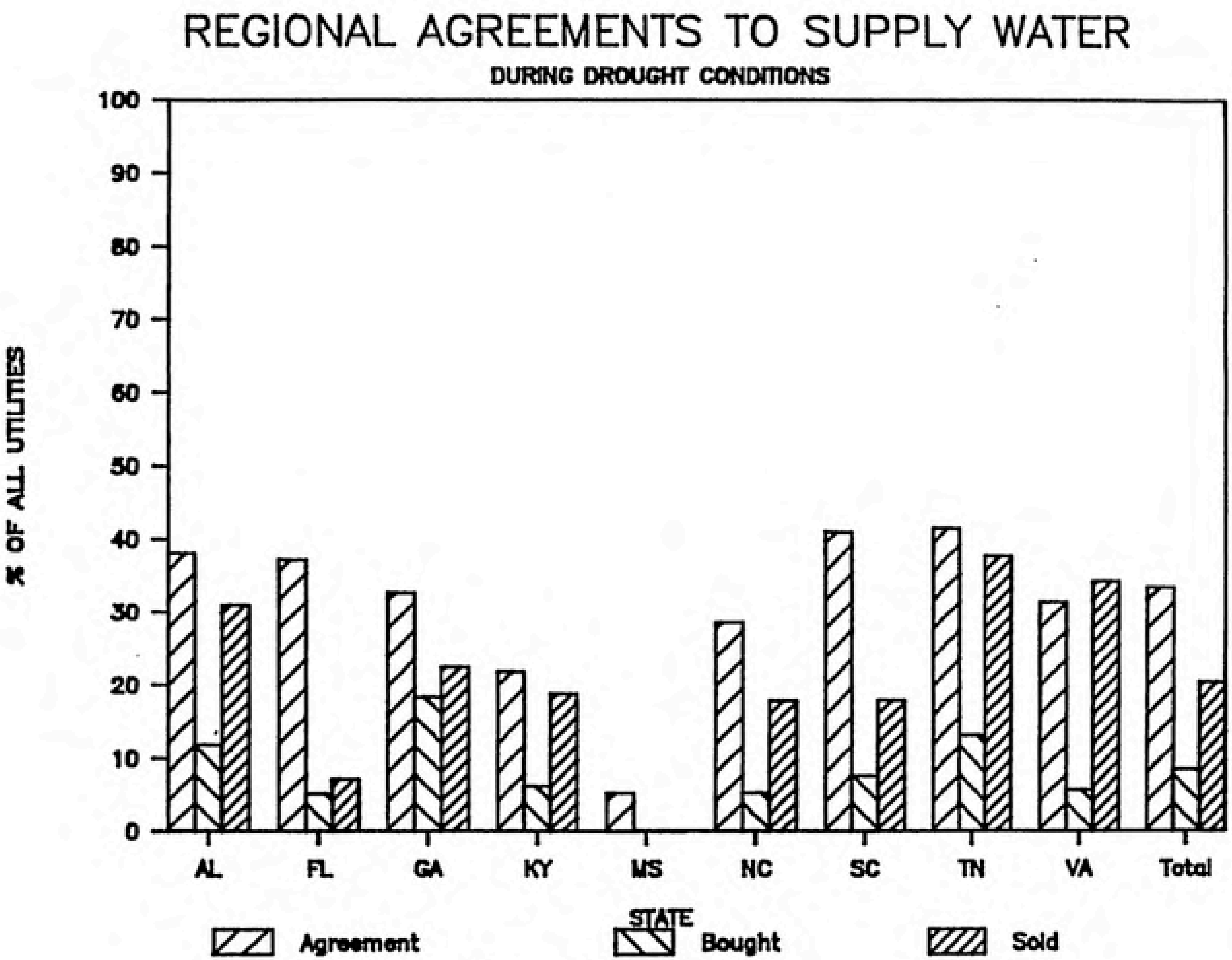

INVOKED POLICY IN '86
% OF ALL UTILITIES
100
90
80
70
60
50
40
30
20
10
0
AL
FL
GA
KY
MS
NC
SC
TN
VA
Total
STATE
Invoke
Vol Cons
Mand. Cons.

Figure 3.3



REGIONAL AGREEMENTS TO SUPPLY WATER
DURING DROUGHT CONDITIONS
% OF ALL UTILITIES
100
90
80
70
60
50
40
30
20
10
0
AL
FL
GA
KY
MS
NC
SC
TN
VA
Total
STATE
Agreement
Bought
Sold


Figure 3.4

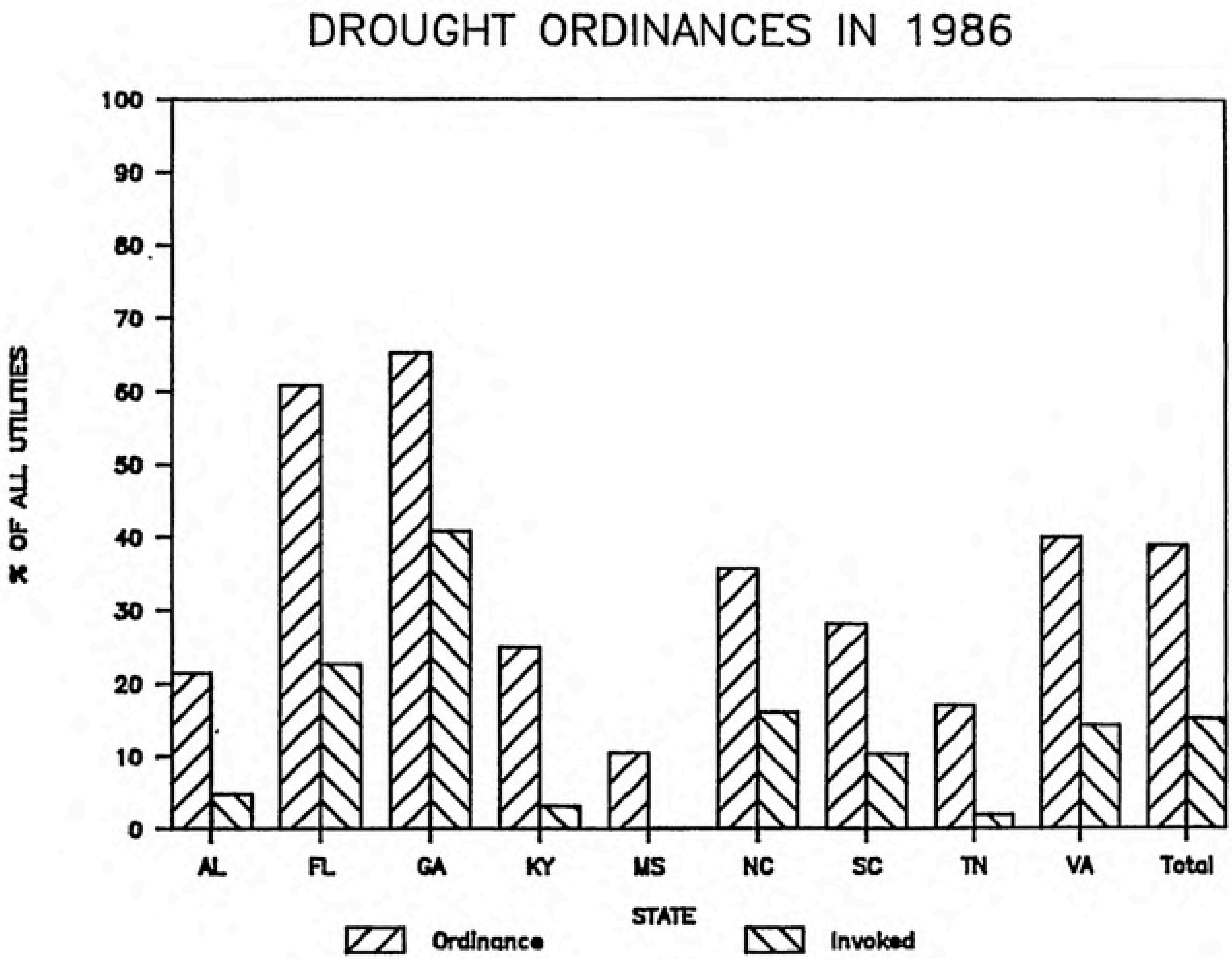

DROUGHT ORDINANCES IN 1986
100
90
80
70
60
50
40
30
20
10
0
% OF ALL UTILITIES
AL
FL
GA
KY
MS
NC
SC
TN
VA
Total
STATE
Ordinance
Invoked

Figure 3.5

# TECHNICAL REPORTS FOR DROUGHT POLICY

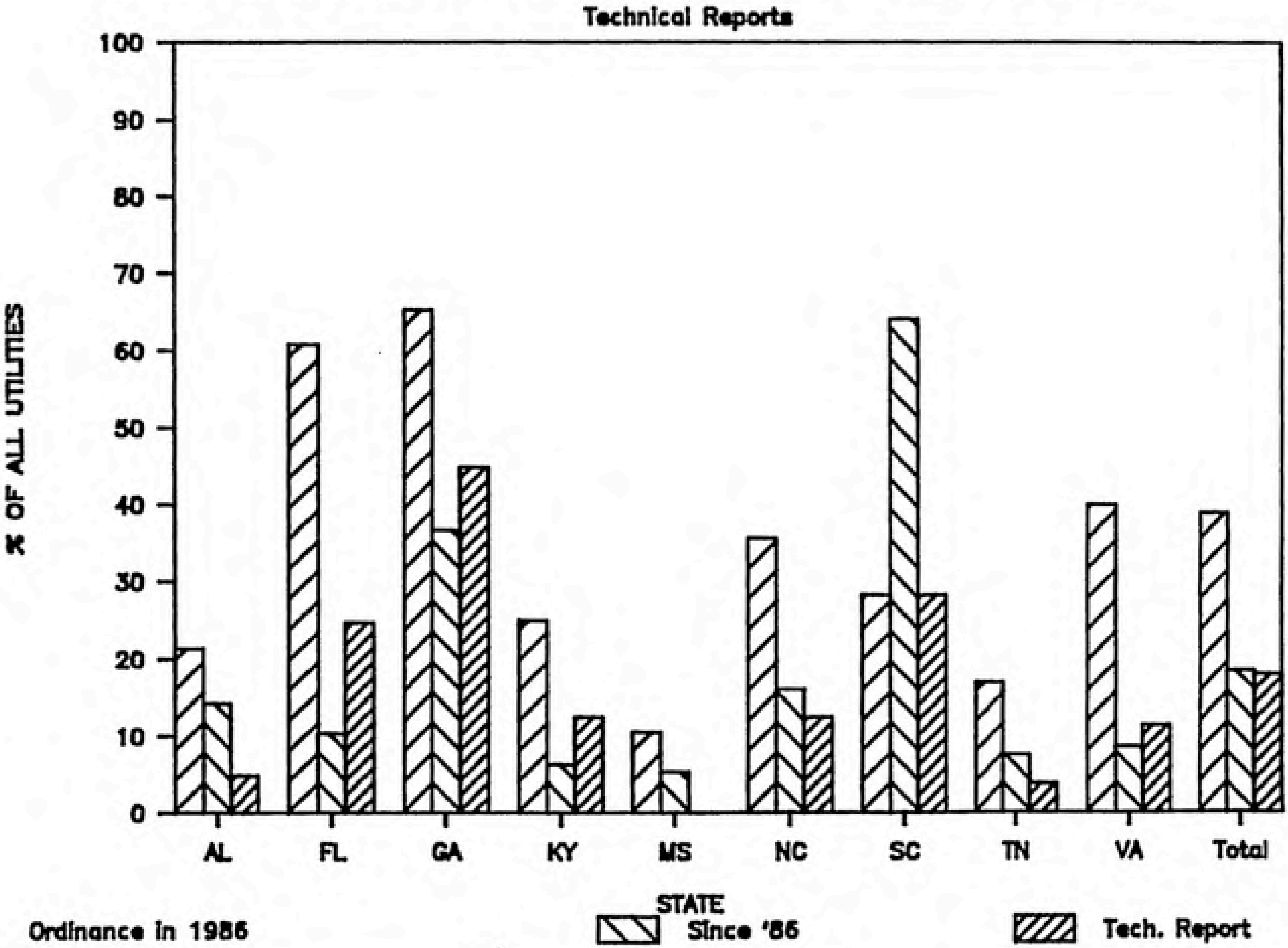



Figure 3.6

Overall Response

The drought of 1986 had varying effects on communities depending on how well prepared each was to face a drought. A total of 40% of those responding asked customers for some sort of conservation. Voluntary conservation measures were put into effect by 37% of the utilities while only 14% implemented mandatory conservation.

One of the problems faced by a large number of utilities was that they had no ordinance or other written policy for operating their water supply under drought conditions. Only 39% had any ordinance for drought management policies in 1986. If a utility's supply will not always be greater than demand, an operating policy would be beneficial. A total of 78 utilities or 18% have developed a policy since 1986. This includes utilities that had a policy in 1986 but felt the need to update or develop a new policy to more efficiently operate their system. Only 18% had a technical report to support the basis for such a policy. This is an extremely low number because it shows that there are little if any technical criteria for operating a water system. Upon speaking with several utility directors that claim to have a technical report, it appears that the main criteria used for decision making are judgment and experience of the water managers. In South Carolina, the main criterian used for following their ordinances is the Palmer Index.

One reason that conservation had to be implemented in several cases is due to the lack of additional sources of water that may be obtained during times of emergency. Obtaining water from other sources can often prevent the need to reduce demand through conservation while avoiding excessive drawdowns on local supplies. One-third of utilities surveyed were party to an agreement with another utilitiy to provide a supplementary supply of water during drought conditions. Of these, 26% (36 of 141) or 9% of the total purchased water under that agreement in 1986. A total of 20% sold water under this agreement in 1986. This difference can be explained by the possibility of these utilities selling to utilities serving under 10,000 people and utilities purchasing from more than one source.

The drought of 1986 may have spurred utilities into increasing supply rapidly. If a system is designed to meet demand for 20 years into the future, then it is expected that about 5% of utilities will increase size of supply each year. However, 32% of those surveyed increased the size of their supply since 1986. Of those that entered some form of consevation, 48% have increased supply since 1986. Of those with intergovernmental agreements, 37% have increased supply and 50% of those who purchased water under that agreement have increased supply.

The utilities that have an operating policy received assistance in preparing it from several sources. Approximately 84% of utilities took part in some form in the preparation of their policy or ordinance. Policies were developed with help from neighboring utilities in 30% of the cases. Of those utilities that developed a policy since 1986, 42% got help from neighboring utilities. Consultants accounted for 25% of all policies developed. The reason this number may not be larger is due to the large expense often incurred in hiring a consultant.

Only 2% of utilities used a university-based technical assistance program to aid in developing a policy. Moreau (1988b) has currently developed working models for Greensboro, Durham, and OWASA. OWASA has currently adapted Moreau's model but still does not follow it verbatim.

A state government technical assistance program was used by 33% of utilities with an operating policy or ordinance. This number varied largely by state. South Carolina gave the largest percentage of assistance to its utilities. This is due to the "Drought Response Act" passed by the South Carolina General Assembly in 1985. "This act required public entities that supply water to develop and implement local drought response ordinances and plans for water conservation programs and alternative water sources. The Drought Response Act also established six regional Drought Response Committees to represent the interests of local governments, agriculture, industry, and domestic water users in each particular region of the state known as Drought Management Areas." (Charleston Comm. of Public Works, 1987). Florida has developed water management districts to manage water supplies in different areas of the state. These districts developed general drought operating policies. The Georgia Department of Natural Resources Environmental Protection Division required all systems to develop and implement a water conservation plan. (City of Griffin, 1984).

Assistance from leagues of municipalities occurred in only 6% of the cases. An increase in this number could allow new developments to be passed on more easily among utilities.

Other sources accounted for about 10% of assistance programs. These sources could be anything depending on how the person who responded interpreted the other six choices.

## Source of Water Supply

Water is supplied to people by two main sources. These are groundwater and surface water. Surface water includes withdrawals directly from streams, rivers, and natural lakes and from reservoirs from impoundments on rivers.

Utilities were divided into those who supply surface waters, those who supply groundwater and those who purchase from another utility. Some utilities use two or all three of these sources.

The split among water suppliers in the Southeast in 1986 was as follows:

Table 3.5 - Source of Water

| | |
|---|---|
| 33% | use surface water only |
| 32% | use groundwater only |
| 10% | purchase water only |
| 7% | use surface water and groundwater |
| 4% | use surface water and purchase water |
| 4% | use groundwater and purchase water |
| 2% | use all three sources |
| 92%* | |

*8% of respondents did not specify their source of water supply.

Of those utilities that only used surface water in 1986, only 12% had the ability to purchase water during an emergency. Of those surface water supplies who also purchased waters, 35% did so due to emergency conditions.

Utilities whose main supply was groundwater had the opportunity to purchase in 20% of the cases. Of those who use groundwater and also purchased in 1986, only 21% (6 in 28) did so due to emergency conditions.

A total of 84 utilities (20%) purchased water in 1986; 17% purchased water throughout the year; while 2% purchased seasonally as needed. In 1986, only 3% of utilities purchased water due to emergencxy conditions. However, 15% did have the ability to purchase during emergency conditions. A promising result of the drought was that only 19% (12 of 64) of those who had the ability to purchase during an emergency had to purchase in 1986 (note: an emergency can consist of shortage due to a number of reasons including drought, pump failure, plant failure, distribution system breakage, etc.).

An interesting result is that groundwater and surface water suppliers seemed to be equally prepared and affected by the drought. 43% of groundwater suppliers asked for some form of conservation, while 40% of surface water systems entered conservation. Mandatory conservation measures were implemented by 14% of groundwater suppliers and 16% of surface water suppliers.

Intergovernmental agreements to provide supplementary supplies of water during drought conditions involved 37% of surface water systems and 36% of groundwater systems. Both surface water and groundwater suppliers bought water under this agreement in 10% of the cases. Surface water systems tended to sell more often; 29% sold water in 1986 compared to 16% of groundwater systems.

Both groundwater and surface water suppliers seemed equally unprepared to operate water supplies during droughts as only 44% and 40% respectively had any kind of formal operating policy or ordinances. Only 17% of groundwater and 20% of surface water suppliers had a report to describe the technical basis for their policy.

Since the drought of 1986 was spread over a wide region, we would expect varying effects on the different states. This also depended on how prepared each state was to face a drought. Some states had already implemented general statewide operating plans and policies, or at least water conservation programs. The results were cross tabulated for each state to see the impact the drought had on individual states and how prepared each was to face it.

**Alabama**

Alabama has 57 utilities that serve over 10,000 people. A total of 42 utilities responded to the survey. Of these approximately 36% are surface water supplies, 29% are groundwater suppliers, 12% use both surface and groundwater and 17% purchase their entire supply. Some surface and groundwater suppliers also purchase water. Only one utility claimed to buy during emergencies.

Only 21% of all Alabama utilities had a drought operating policy or ordinance in 1986. Since 1986, 14% have adopted a policy. Only 2 ( 5%) utilities had any technical basis for this policy.

Because of the drought, several utilities were forced to make decisions without following any formal policy. Conservation measures were taken by 36% of utilities but only 13% of these (2 in 15) did so under an ordinance that was invoked in 1986. Only 13% (2 in 15) of those who entered conservation implemented mandatory conservation.

Thirty-eight percent of all utilities had agreements to provide a supplementary supply of water during drought conditions. Of these, 44% had to implement conservation measures any way. Thirty-one percent bought water under this agreement. Of those who purchased, 80% (4 of 5) also entered conservation.

The impact of the drought also caused many utilities to realize the need to increase the size of their supplies to meet increased demand during all conditions. Almost 38% of utilities increased the capacity of their water supply since 1986. Of those who entered conservation, 47% (7 in 15) increased their supply capacity.

**Florida**

Florida consists of 149 water utilities who serve 10,000 or more people. Of these, 97 or 65% responded to the survey. In the past several years, Florida has established 5 regional water management districts to set up guidelines for utilities in managing their water supplies. Utilities in Florida are advised by their respective water management districts as to severity of drought conditions. Utilities also rely on water management districts for legal clout for restrictions on water use.

Florida is mainly served by groundwater supplies. Only 8% of utilities rely solely on surface water and a total of 13% use surface water to some extent. Only 5% of the systems purchase their entire supply of water.

A 1982 "Survey of Water Conservation Programs in the Fifty States" (Blackwelder & Carlson, 1982) showed Flordia falling behind other states in several areas of water conservation including drought contingency planning. However, at the time Florida introduced a new water management policy which emphasized nonstructural approaches. This was considered the most innovative policy at this time. Presently it seems that Florida is one of the most prepared states throughout the Southeast to face drought situations.

Several utilities in southern Florida felt no effects of the 1986 drought. They did, however, feel a severe drought in 1985. The drought of 1985 exceeded an estimated frequency of once every 100 years.

Compared to the Southeast as a whole, Florida was generally better prepared to operate their systems under drought conditions. Nearly 61% of all Florida utilities had a written policy or ordinance to operate their sytems under drought conditions in 1986 compared to the Southeast as a whole in which only 39% had ordinances. An additional 10% have adopted a policy since 1986. Only 35% of those with a policy have a report that describes the technical basis for decision making. Again, we see that actual decisions are often made by judgment and experience.

Obviously, many areas of Florida were severely affected by the drought, resulting in 46% entering conservation of some type. Voluntary conservation was implemented by 43% of utilities and mandatory conservation was entered by 19% of all utilities. Three percent of utilities skipped voluntary and went straight to mandatory. Of those utilities who asked for voluntary conservation measures, 71% had ordinances and 84% of those who implemented mandatory measures, had an ordinance.

Regionalized water supplies does not seem to be a prevalent method of supplementing ones water supply during drought periods in Florida. While 37% of utilities said they had an agreement to provide a supplemental water source during droughts, only 5% bought water and 7% sold water under this agreement in 1986. Also several utilities claimed they could buy water during emergencies such as system breakdown, but they said they could not purchase during droughts. Only 1 in 5 utilities who purchased did not enter any form of conservation. Purchasing water should be the first alternative to conservation if at all possible.

Parts of Florida have faced dry years throughout the 1980's. Water management districts are constantly looking into ways to increase or reduce demand. Water reuse has gained particular attention in areas such as St. Petersburg. Even with plans to implement long-term conservation techniques, supply augmentation is still prevalent here. Since 1986, 46% of all utilities have increased supply. Of those who entered conservation in 1986

64% have increased supply. The problem here is that population is growing while supply is dwindling. Long-term conservation techniques and water reuse must seriously be considered to reduce Florida's growing demand.

While Florida has had and continues to develop intensive water operating policies, they must consider the effectiveness of what they have. Several utilities base their decision making on their water management districts (WMD). They do not have a clear, set criteria for making their own decisions. Presently, it appears that those utilities with a written operating policy for drought conditions are in much better shape when it comes to making it through a drought unscathed.

**Georgia**

Georgia consists of 62 water utilities serving 10,000 or more people. Supplies are split fairly equally between ground water suppliers and surface water suppliers. In 1981, the Georgia Department of Natural Resources published the Georgia Water Conservtion Guidebook. The Georgia EPD (Environmental Protection Department) set guidelines to use as a technical basis for drought management policies. This has spurred water utilities to prepare special operating policies during drought conditions.

In 1986, 65% (32/49) of all utilities had operating policies or ordinances. Sixty-three percent (20/32) of these utilities implemented their ordinance in 1986 due to the drought. Since 1986, 37% (22/49) have adapted a policy.

The drought was so severe that 71% of all utilities adapted water use restrictions. Voluntary restrictions were asked for by 61% of the communities and mandatory measures were implemented in 49% of Georgia utilities. Of those utilities with a policy, 67% asked for voluntary measures and 62.5% resorted to mandatory water restraints.

Intergovernmental agreements were about the same as those for the entire Southeast with 33% of utilities having some form of agreement. Under this agreement, 18% of all utilities purchased water while 22% sold. This is a case where some utilities both bought and sold water. Sixty-seven percent of those who purchased also entered conservation and 82% of those who sold entered conservation. It is quite interesting that utilities would continue to sell water even when they must conserve themselves.

A high number (50%) of Georgia utilities have also increased the capacity of their supply since 1986. More than half of those who entered consevation have increased supply. Surface water supplies were more affected by the drought with over 90% calling for conservation while 48% of groundwater suppliers called for reductions in water use. Sixty-two percent of surface water suppliers implemented an ordinance while only 24% of groundwater suppliers did so.

**Kentucky**

Kentucky has only 44 systems that serve 10,000 or more people. Of these at least 67% are surface water supplies. Rather than drawing water from impoundments, many municipalities draw directly from free flowing rivers such as the Ohio River. The state has developed a general water conservation plan to be used during droughts. However, local utilities have been slow to adapt this.

Overall only 25% of utilities had any formal operating policy in 1986. Since then an additional 6% have adapted policies. Local municipalities did not seem to be adversely affected by the drought. Large river flows were able to pull many utilities through the dry weather without any problems. Blackwelder and Carlson found "nothing outstanding with the state's water conservation program," This seems to still be the case, however utilities are slowly moving toward adapting drought management policies.

**Mississippi**

Mississsippi has only 31 utilities serving 10,000 or more people. The state is generally serviced by ground water except for 2 utilities who have surface water supplies. The state is generally blessed with an abundance of water and felt little if any effects of the 1986 drought.

The two cities with surface water supplies were the only ones to have an ordinance. Only 1 of these had a technical basis for its policy. If a major drought were to hit Mississippi for an extended period, it might not be prepared make quick decisions on supply and demand management.

**North Carolina**

North Carolina has 60 utilities that serve over 10,000 people. Surface water is the dominant source here serving about 75% of communities. Two communities also purchase from surface water impoundments. About 20% of utilities use ground water.

Parts of North Carolina were severely impacted by the drought. Only 36% of utilities had a written policy and only 13% had a technical basis for this policy. Even with a policy, many cities were unable to determine the possible outcome of making certain decisions regarding interbasin transfers and the imposition of various conservation measures. Many utilities relied on past experience; yet, they did not realize the severity of the situation. City managers seemed not to have set criteria to base their decisions on.

The drought resulted in some form of water use restrictions being imposed by 39% of North Carolina cities. Only 11% eventually implemented mandatory measures, but this could be due in part because some utilities did not have the power to implement mandatory restrictions.

Intergovernmental agreements for water exchange during droughts were somewhat prevalent in certain regions of North Carolina. A total of 29% of utilities had agreements to provide a supplementary supply of water under drought conditions. Nineteen percent purchased under this agreement, while 63% sold water in 1986.

Since 1986, 18% of all utilities have increased supply. However, of those who implemented conservation, 36% have increased system capacity.

MAP A

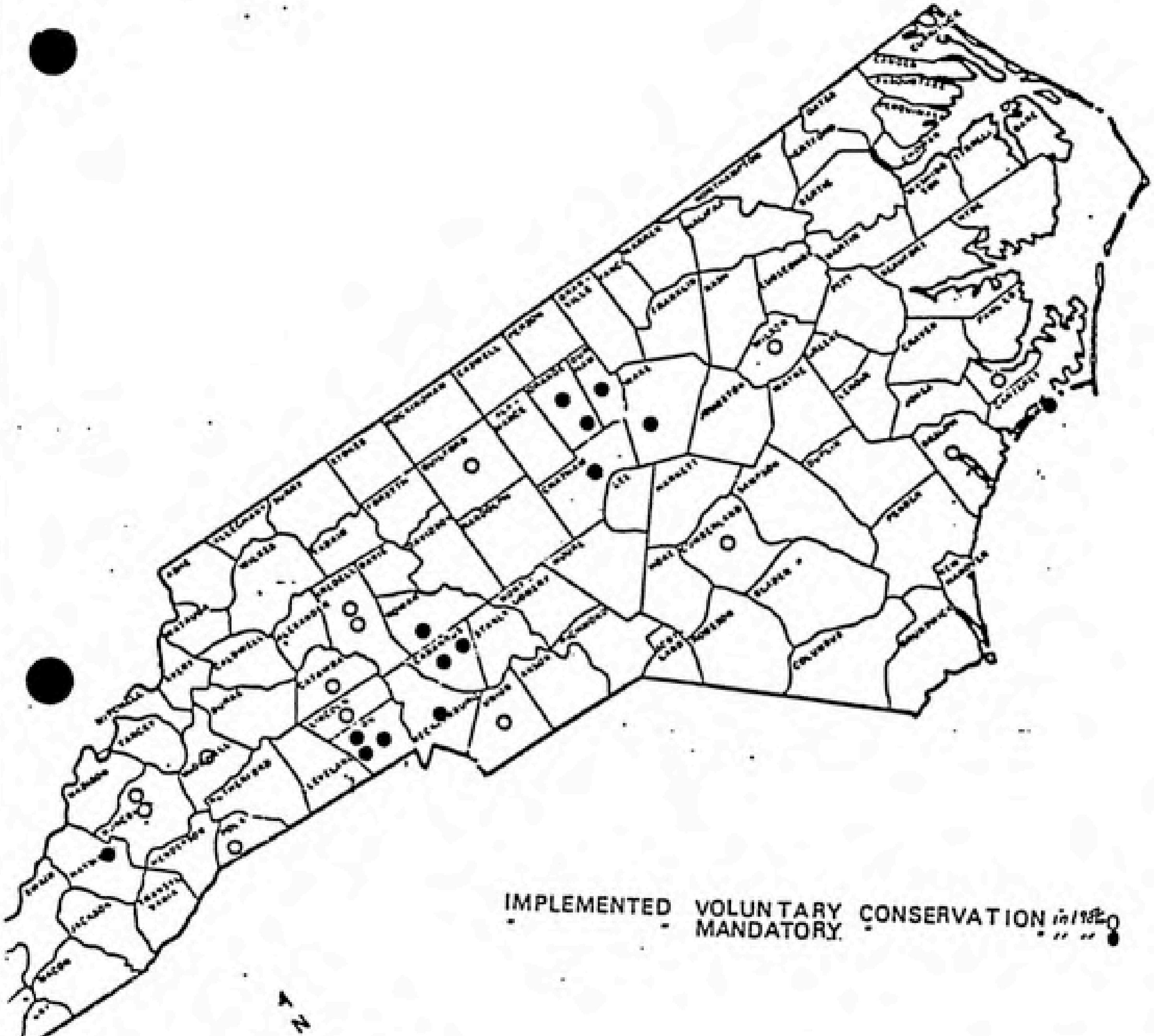



Figure 3.7

Source: Shea (1988)

Interestingly while almost half of those utilities who used conservation in 1986 had an ordinance already, an additional one-third have adopted an ordinance since then.

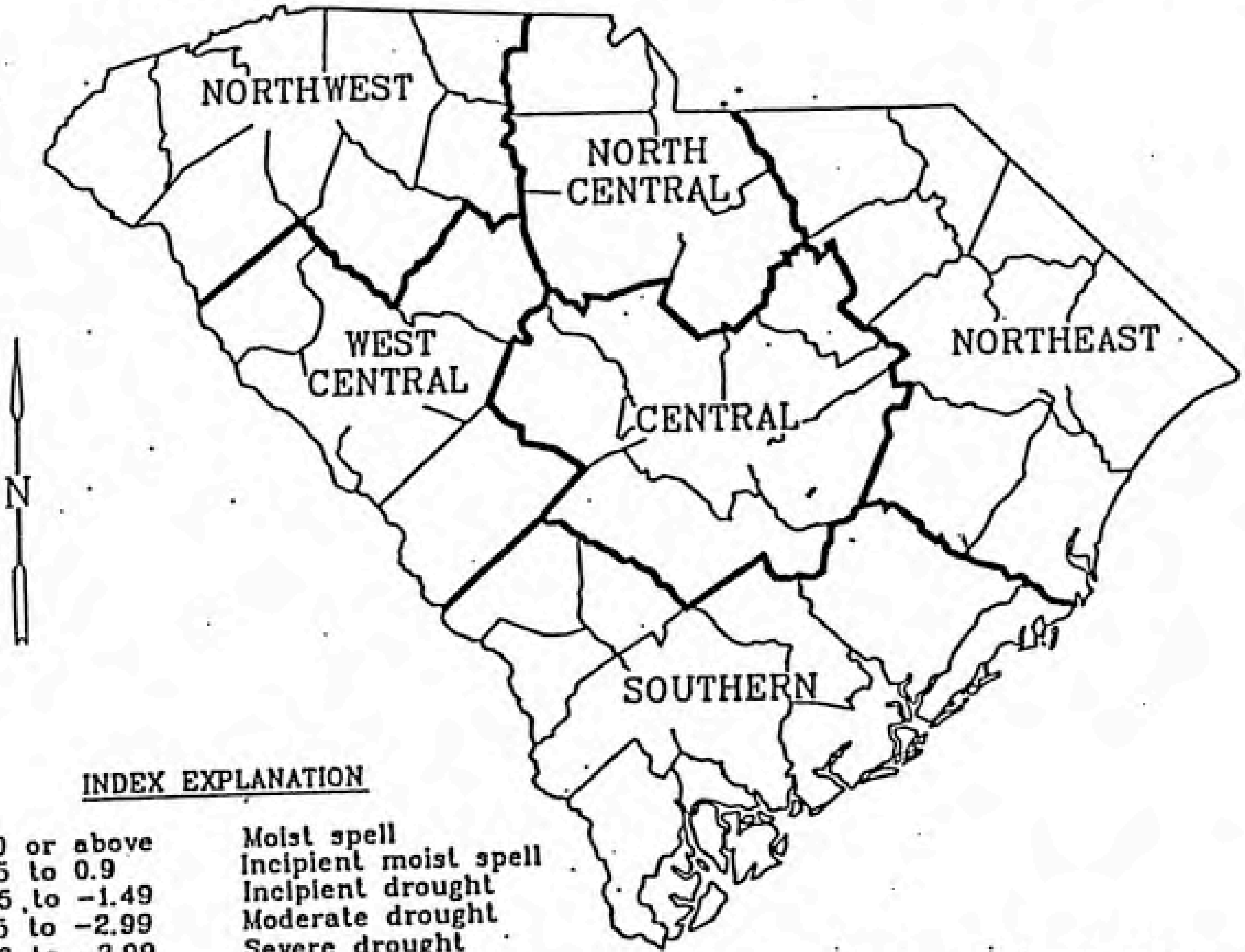
**South Carolina**

South Carolina serves 49 communities of 10,000 or more people. The South Carolina Drought Response Act of 1985 established 6 Drought Management Areas (DMA) shown in figure 3.4). The act also requires utilities to develop and implement local drought response ordinances and plans which identify alternate water sources and a water reduction program. South Carolina consists mainly of surface water supplies, but some large supplies are from groundwater. It also has a groundwater management program to limit withdrawals to under 100,000 gpd.

Even though the state had passed the Drought Response Act in 1985, only 28% of utilities had an ordinance or plan during the 1986 drought. Since 1986 however, more than 64% of citities have developed an ordinance. Also 28% of utilities in SC have a technical basis to support their plan.

South Carolina definitely felt an impact due to the drought, with 59% of municipalities calling for various conservation measures. Voluntary conservation was asked for by 51% of utilities and mandatory conservation was implemented in 13% of the cases. Of those utilities who already had an ordinance in 1986, 55% used voluntary conservation and 27% imposed mandatory limitations on water use.

# DROUGHT MANAGEMENT AREAS




INDEX EXPLANATION

| | |
|---|---|
| +1.0 or above | Moist spell |
| +0.5 to 0.9 | Incipient moist spell |
| −0.5 to −1.49 | Incipient drought |
| −1.5 to −2.99 | Moderate drought |
| −3.0 to −3.99 | Severe drought |
| −4.0 or above | Extreme drought |

Produced by SCWRC Cartographic Lab

Source: City of Charleston, Commisioners of Public Works

FIGURE 3.8

Intergovernmental agreements for water exchange during droughts involved 41% of all utilities. This is somewhat higher than the rest of the Southeast and may be due to the DMA's. However, only 8% of utilities purchased water under this agreement in 1986 but none of those who purchased had to enter mandatory conservation. However, 19% of those who had agreements used mandatory instead of purchasing to help get through the drought.

The impact of the drought was also shown in that 36% of municipalities have increased capacity of their supply since 1986. Also, more than half of those who used some form of conservation have increased supply.

**Tennessee**

Tennessee consists of 65 utilities serving 10,000 or more people. Tennessee consists of about 46% surface water suppliers, about 28% ground water, 18% whose source is both surface and ground water and 7% who purchase their entire supply.

Blackwelder and Carlson (1982) showed no outstanding features of the state's water conservation program. This trend seems to have continued with limited drought contingency plans throughout the state's utilities. Only 17% of utilities had a plan in 1986. While Tennessee was moderately impacted by the drought, only one utility implemented its ordinance. Less than 8% of utilities have developed a policy since 1986. A disappointing state of drought readiness shows in the statistic that only 4% of all utilities had a technical report to go along with their ordinance.

The drought was moderate with 26% (14/53) of utilities calling for voluntary conservation but only one utility imposing mandatory conservation.

One significant factor in Tennessee was that 42% of the cities had agreements for the emergency sale and/or purchase of water; 13% did purchase water under this agreement in 1986. More significantly 20 of 22 sold water in 1986.

Capacity of water supply was increased by 21% of utilities. Only 6% of all utilities entered conservation and then increased supply since 1986.

**Virginia**

Virginia has 56 utilities that serve at least 10,000 people. Several of these serve large populations of 50,000 or more. Only 63% of Virginia utilities responded to the survey, thus limiting the accuracy of these results. The main source of supply in Virginia is surface waters serving about 70% of the cities. Groundwater accounts for 10% of supplies and 20% of utilities purchase their entire supply.

Virginia is active in the water conservation area and in drought contingency planning (Blackwelder and Carlson,1982). They are also involved in regionalizing supplies where possible.

Although the state as a whole is involved in drought management, only 40% of cities had a written policy. An additional 9% have added a policy since 1986. Of those with a policy 36% invoked it in 1986.

Overall 26% of utilities entered some form of conservation in 1986. Only 6% called for mandatory restraints, though.

Fourteen percent of all utilities called for consrevation measures under an ordinance.

In Virginia, 40% of all utilities purchase at least part of their water throughout the year. Agreements for water exchange during droughts involve 31% of utilities. Although interbasin transfers are prevalent here, only 6% of utilities claimed to have purchased water under emergency conditions in 1986.

Since 1986, 9% of utilities have increased size of supply. This is expected for a 2-year period.

Virginia seems to have been moderately affected by the drought. Only 11% of utilities were prepared with ordinances that have a technical basis. Many utilities may have acted without knowledge of the risk they faced.

## Conclusions

Extensive areas of the Southeast were affected by the drought of 1986. The states of North Carolina, South Carolina and Georgia faced the most severe conditions.

South Carolina has significantly improved their drought management policies over the past few years. While a good number of utilities presently have drought management policies, too few have any technical basis for this. Those who do have a technical basis often use criteria such as the Palmer Drought Serveity Index. While this is a good indication of drought severity, it tells little about the implications to individual water supplies. Criteria used should be representative of the specific system using it. Water managers need sufficient information on the risk they face of running out of water.

The extent to which utilities were affected varied with how prepared they were to manage their systems under these conditions. Few utilities had prepared plans to help in decision making. A lack of inter-local agreements and a minimum of technical criteria to guide in decision making may have led to dangerously low drawdowns on water supplies.

Without the backing of an ordinance in many cases, it may have been impossible to implement mandatory restrictions that could have further reduced demand.

If another drought continued through 1988, Georgia, Florida, and South Carolina would be the best prepared states to face it.

It is not difficult to determine that there is a water shortage, what is difficult is to determine the extent of the problem and what can be done to survive it with minimal impact.

## CASE STUDIES

The drought of 1986 had varying effects on different water supplies throughout the Southeast. The variation in effects was not just regional, but varied from city to city depending on the state of their water supplies and their operating policies. Four utilities in the piedmont of North Carolina, separated by only 60 miles, are examined to determine how they managed their systems during 1986 and how well those systems performed.

The four utilities studied in this part of the survey were the City of Durham, Orange Water and Sewer Authority (OWASA), the City of Greensboro, and the CitY of High Point. Personal interviews were conducted with the water utility managers to determine the state of their operating policies during the drought of 1986. The utility directors also expressed personal opinion in answering questions.

The following questions were put to the utility directors:

1. What is the status of your intergovernmental agreements? Do you have any written or unwritten agreements to provide or obtain a supplementary source of water during drought conditions and with whom?
2. What are the criteria used (if any) for decision making during droughts? How do you decide to enter different levels of conservation?
3. What methods were used to help in decision making (such as simulation models or risk tables)?
4. What are the contents of your ordinance for operating your water supply during droughts?

5. What techniques were used to inform the public about the situation and the content of your ordinance?
   - When and how were the public informed?
   - Do you have an ongoing public education program? (such as)
     - Workshops
     - Demonstrations
     - Bill inserts
6. What was the performance of implementing different levels of conservation?
   A. Compare with and without conservation
   B. When were different stages of conservation taken?
   C. What were the demand levels for each period?
   D. When did storage bottom out?
   E. What would reservoir levels have been with no policy?
7. What are your methods for obtaining data on your system?
   A. Reservoir levels - who reads, how often, and how are data transmitted?
   B. Streamflows - gage, who reads, who interprets stage-discharge curves, how transmitted?
   C. How do you estimate evaporation?
   D. How do you estimate demand with and without conservation?

**High Point**

The City of High Point, NC, serves a population of 70,000 people with 17,500 residential connections and a total of 25,000 connections including commercial and industrial accounts. Usage is split approximately 50% residential and 50% commercial. The city is served by two reservoirs. They are Oak Hollow Lake with a capacity of 3.2 billion gallons and High Point City Lake with a capacity of 1.2 BG for a total system capacity of 4.4 BG. The safe yield of this system is 25 MGD. The average daily demand in 1986 was 11.5 MGD. High Point is curerntly served by two water filtration plants.

High Point may serve as an extreme case due to the excess capacity of their system. High Point does not currently, nor did it have any intergovernmental agreements in 1986 to buy or sell water during drought or emergency conditions. This is partially due to the capacity of the reservoirs being able to supply the system at the current rate of demand for more than a year (383 days) before running out of water. High Point is also appropriately named because it is located at a point of high elevation relative to the surrounding area. This makes it nearly impossible to be supplied by surrounding communities because none are of sufficient pressure to reach High Point's system.

High Point did not have a problem meeting demand in 1986 and therefore did not experience effective drought. They do not have any set criteria that are used for decision making under drought conditions. O'Neill (1988) stated that engineering judgment and keeping an eye on reservoir drawdown is the main method for decision making during droughts. This may involve looking at historical records and long-term weather forecasts.

The High Point city code contains a generic ordinance for emergency water conservation. However, there are no specific criteria governing its implementation.

In 1986 High Point did not enter either voluntary or mandatory conservation. However, there was an increasing public concern because of the situation in Greensboro and other municipalities throughout the state. People wanted to know why they weren't told to conserve when everyone else was doing so. The city then made people aware of water conservation techniques through newspapers, television, and radio. However, this was not a request for voluntary conservation. A concern of the city was that they are in the business of selling water. If they ask people to conserve, even though they feel they have an ample supply, they will lose money. Also the effects of a conservation program often continue for many years to come, resulting in lost revenues for the city for several years.

High Point is currently developing predictions for demand levels. This is being done through electronic meter readings and SCADA systems. Predicted demand levels can be used to determine increased demand due to dry weather and the reduction in demand due to conservation.

Data are obtained and kept by plant operators. Reservoir levels are read twice a day and kept on file at the treatment plant. Flow through the treatment plants is measured manually. Evaporation is determined by subtracting usage from drawdown. Historical records are used for predicting future evaporation.

Greensboro

The City of Greensboro, NC, serves a population of 170,000 people with 60,000 residential connections and 4,500 commercial and industrial connections. The city is served by three reservoirs. They are Lake Townshend, with a capacity of 4.0BG, Lake Brendt with a capacity of 2.2 BG, and Lake Higgins with a capacity of 1.2 BG. The system capacity is 7.4 BG. The safe yield of the system is 37 MGD. The average daily demand of the system in 1986 was 26.4 MGD.

Greensboro has no intergovernmental agreements, written or unwritten to buy or sell water during emergency situations.

The criterion used to determine if water conservation is necessary is a capacity use curve as shown in fig 4.1. This shows a plot of supply remaining over a six-month time span at an average daily demand of 33 MGD and 6 BG in the reservoir on August 1. If the actual supply falls below a given amount, then conservation should be considered to raise it back up above this level. Other criteria used to make decisions on conservation were the use of long-term weather forecasts and the use of historical data for rainfall and stream flows for upcoming months.

Greensboro does not currently use simulation models or any type of risk tables showing the probability of meeting demand. Only the capacity use curve and engineering judgment are used.

There is currently no written ordinance for operating their system under drought conditions. However, the water department does have a plan. This would be similar to ordinances used by

City of Greensboro

# TARGET RESERVES FOR CONSERVATION PROGRAM

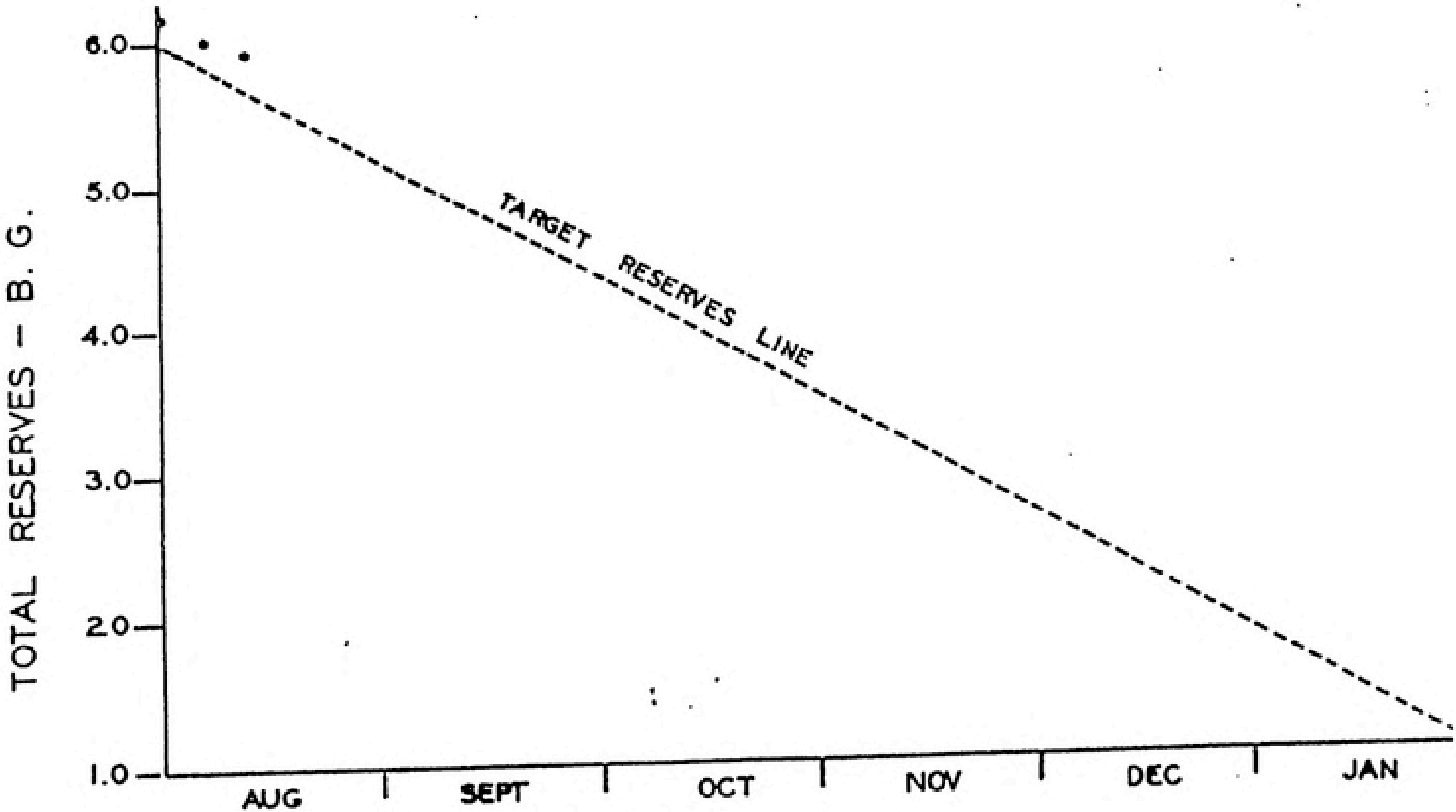



Figure 4.1

other utilities. An emergency meeting of the town council could be called to put an ordinance into effect. Besides the basic conservation measures common to many water operating policies, Greensboro could implement a 500% surcharge for use over a normal 200 gal/household/day, under mandatory restrictions.

It was decided to implement voluntary conservtion on July 22, 1986, with a goal of 10% reduction in demand. The public was informed through the use of newspapers, TV, and radio. People were asked to use common sense in water usage. They were advised of the common conservation techniques and asked to cut back on outside water usage. Phase 2 conservation called for mandatory conservation. This included no lawn sprinkling, no car washing, and a surcharge for those who used over 75% of their normal demand. The objective of phase 2 was 25% reduction in demand from the demand encountered during a drought. This should bring demand back to the average demand when there is no drought. Phase 3 involved cut offs, fines, and surcharges for not meeting mandatory restrictions. However, neither phase 2 nor phase 3 restrictions ever went into effect because of significant rainfall on August 10, 1986.

The results for phase 1 or voluntary conservation seem significant; however, other factors such as cloud cover may have played a role here. Greensboro predicted an average drought demand between 35 and 38 MGD from historical records of past dry years. Data for demand in July, before conservation went into effect, show this to be a good estimate of demand. The week ending July 6 had an average demand of 26.6 MGD which was approximately Greensboro's average daily demand for 1986. As the drought worsened, demand increased to 36.1 MGD for the week ending July 13 and 37.6 MGD for the week ending July 20. Voluntary conservation was implemented on July 22, 1986. A decline in water usage was evident almost immediately with the average demand for the week ending July 27 reduced to 30.7 MGD showing a 19% reduction from the previous week's use. This trend continued with demand reaching 28.7 MGD, for the week ending August 3, a 24% reduction. Reservoir levels bottomed out on August 10 with demand of 27.8 MGD (a 26% reduction in use from July 20). Significant rainfall then occurred with 5"-6" of rain falling from August 10 through August 12. Lake Brant filled in 24 hours and Lake Townshend's water level increased by 17" due to this rainfall. The goal of voluntary conservation was to reduce drought demand by 10% (this value was obtained from literature) but demand was actually reduced by more than 20%. Even if cloud cover did play a role in reducing demand, it seems that a concerned public played an important role in saving water through voluntary conservation.

Data collection methods include measuring lake levels daily and keeping a daily log on record at city hall. Stream flows are not gauged however. Evaporation is estimated from a pan located in Greensboro. The values obtained from this pan were compared several years ago to those measured by the official pan in Chapel Hill. The values seemed to correlate well, therefore Greensboro has used their own readings since this time. The estimated evaporation can then be used to determine inflow into the reservoir because this is not gauged. Demand is estimated from historical records durng dry years. Demand, when voluntary or mandatory conservation is in effect, is estimated by values obtained in the literature for average reductions due to conservation measures.

**Durham**

The City of Durham serves 147,000 people with 49,300 residential connections and 3,300 commercial connections. The city's main source of supply in 1986 was Lake Michie with a safe yield of 21 MGD. Water is also withdrawn from the Eno River at a maximum rate of 5 MGD, but is limited to when river flow is greater than 10 CFS. Water was also available for purchase from Butner's Lake Holt at a maximum of 3 MGD. Since 1986 the Little River Reservoir has been completed adding an additional 21 MGD to the safe yield. The average daily demand was 20.74 MGD in 1986.

Durham had intergovernmental agreements with two neighboring utilities in 1986. An agreement with the Orange Water and Sewer Authority (OWASA) allowed for the sale of up to 4 MGD of treated Durham water to OWASA to meet the needs of OWASA during emergency situations. This would allow OWASA to meet their demand if it could not be met by their own supply. Durham, however, does not have to sell to OWASA if it will prevent them from meeting their own demand. Durham also had an agreement to purchase up to 3 MGD of raw water from Butner during emergency situations. Butner was not required to sell water to Durham. This is a situation that could occur if Butner ran into water quality problems when its reservoir level got too low, such as occurred in 1987. Also at times Butner may be unable to meet the excess demand incurred by selling to Durham. Butner may also sell up to 3 MGD to OWASA, which would be treated first by Durham. In 1986, Butner sold up to 2.9 MGD to Durham during August. At this time Durham was also selling 3 MGD to OWASA.

Durham used a technically based report developed by Research Triangle Institute (RTI) in 1982. This report uses a set of risk tables based on current reservoir levels and the previous month's stream flows. The tables show the probability of sustaining a given demand at a given reservoir level (see Fig. 4.2 & Table 4.1). When to enter a given stage of conservation is based on engineering judgment. Durham's water use ordinance contains six stages the first of which (continuing voluntary conservation practices) is always in effect. (see ordinance in Appendix A.2)

Stage 2 (voluntary conservation) will be entered if the probability of sustaining a given yield drops to 90%. Stage 3 (moderate mandatory cons.) will be entered if the probability of meeting demand drops to 80%. Stage 4 (mandatory cons.) will be put into effect when the probability reaches 75%. To return to stage 2 from stage 3 the probability of meeting demand must reach 95%.

These risk tables were developed from 16 years (1965-1985) of demand data using the ratio of Mo. Mean Demand to Annual Mean Demand. Two thousand years of hypothetical stream flow data were generated from 55 years of actual data. This is used to determine if the reservoir will meet a given demand at any level the reservoir begins a month at, depending on the previous month's flows in the Flat River. The probability is the percent

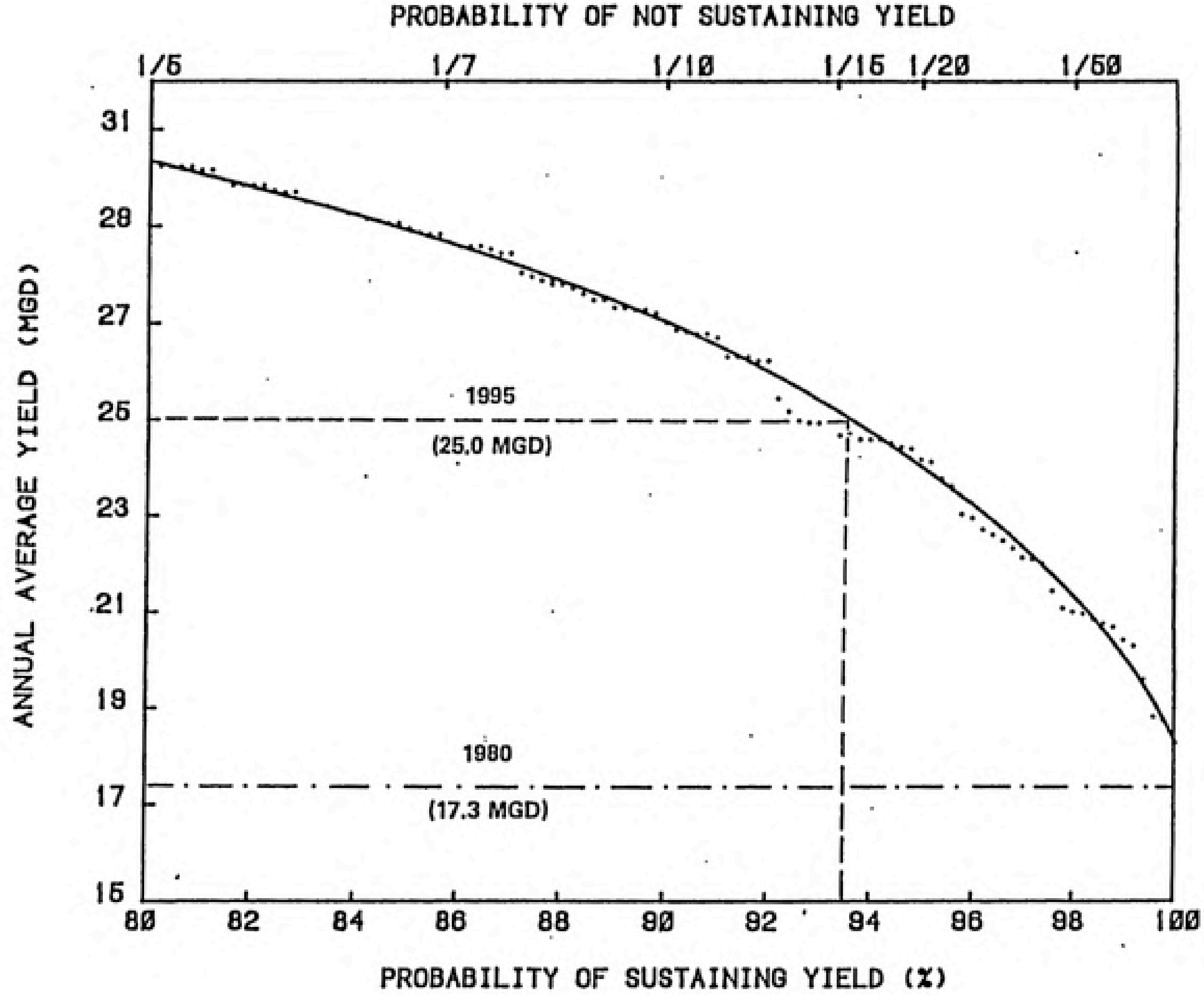



Figure 4.2 Safe Yield from Lake Michie

Source: Mc Crodden & Paddock (1982)

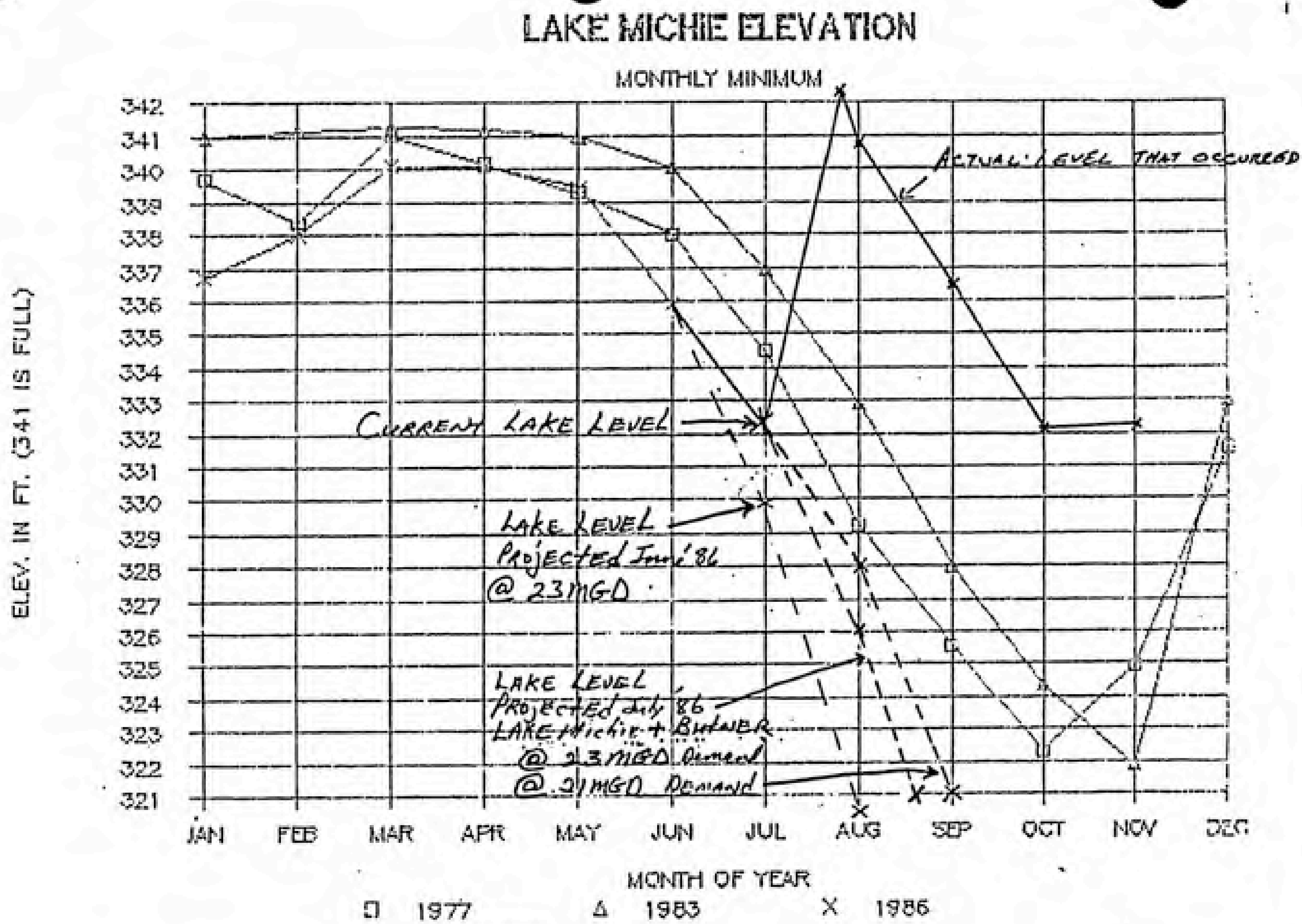



Figure 4.3

Source: City of Durham

Average Flat River
Flow For June
0.00 — 11.8 cfs

# TABLE 4.1

YIELD FROM LAKE MICHIE
(Millions of Gallons per Day)
for

## JULY

| Reservoir Level (ft. above MSL) | Probability of Sustaining Yield (%) | | | | | | |
|---|---|---|---|---|---|---|---|
| | >95 | 95 | 90 | 85 | 80 | 75 | 50 |
| 341 | | 24 | 24 | 25 | 25 | | |
| 340 | | 23 | 23 | 24 | 24 | | |
| 339 | | 22 | 22 | 23 | 23 | | |
| 338 | 19 | 21 | 21 | 22 | 22 | 30 | |
| 337 | | 20 | 20 | 21 | 21 | 29 | |
| 336 | | 19 | 20 | 20 | 20 | 28 | |
| 335 | | 18 | 19 | 19 | 19 | 27 | |
| 334 | | 18 | 18 | 18 | 18 | 26 | |
| 333 | | 17 | 17 | 17 | 17 | 26 | 30 |
| 332 | | 16 | 17 | 17 | 17 | 25 | 29 |
| 331 | | 15 | 16 | 16 | 16 | 24 | 28 |
| 330 | | 15 | 15 | 15 | 15 | 23 | 27 |
| 329 | | 14 | 15 | 15 | 15 | 22 | 27 |
| 328 | | 13 | 14 | 14 | 14 | 22 | 26 |
| 327 | | 13 | 13 | 13 | 14 | 21 | 25 |
| 326 | | 12 | 12 | 13 | 13 | 20 | 25 |
| 325 | | 11 | 12 | 12 | 12 | 19 | 24 |
| 324 | | 11 | 11 | 12 | 12 | 19 | 23 |
| 323 | | 10 | 11 | 11 | 11 | 18 | 22 |
| 322 | | 10 | 10 | 10 | 11 | 17 | 21 |
| 321 | | 9 | 9 | 10 | 10 | 15 | 21 |
| 320 | | 8 | 9 | 9 | 10 | 14 | 20 |
| 319 | | 8 | 8 | 9 | 9 | 13 | 19 |
| 318 | | 7 | 8 | 8 | 9 | 12 | 18 |
| 317 | | 7 | 7 | 7 | 8 | 11 | 17 |
| 316 | | 6 | 6 | 7 | 8 | 10 | 17 |
| 315 | | 6 | 6 | 6 | 8 | 9 | 16 |
| 314 | | 5 | 5 | 6 | 6 | 7 | 15 |
| 313 | | | | 5 | 5 | 5 | 14 |
| 312.5 | | | | | | | 14 |
| Reservoir Level (ft. above MSL) | | 1/20 | 1/10 | 1/7 | 1/5 | 1/4 | 1/2 |
| | | Probability of Not Sustaining Yield | | | | | |

Source: McCrodden & Paddock (1982)

of time the demand will be met.

The decision as to what stage to enter is based on predicted reduction in demand due to the type of conservation. The following values are the predicted savings due to conservation and were determined from experience and literature.

Table 4.2

Voluntary Conservation - 10% reduction

Mod. Mandatory - 15%-20% reduction

Mandatory - varies ( 20%)

A change in the ordinance was made in 1986. This allowed for special use permits. Commercial users such as golf courses and car washes could use methods that broke stage III of the ordinance if they showed they could still meet a goal of 30% reduction.

The public was kept informed of the drought situation and of what stage of the ordinance they were in through the use of local newspapers, television, and radio public service announcements.

In 1986, Durham went about implementing the ordinance as follows. On July 1, the Mayor made an official public announcement on voluntary conservation. On July 7, the city council set stage 3 to be effective July 8. Stage 2 was bypassed because of the severity of the situation. Stage 3 remained in effect until August 20, 1986. During this time letters were sent out to large commercial users, car washes, and sit-down restaurants. The letters notified these users that stage 3 was in effect and what was required of them under stage 3. They also contained a copy of the ordinance. Restaurants could only serve water upon request and were given cards providing customers information on water conservation. Pamphlets on "Water Conservation at Home ... Why to - Where to - How to - " (AWWA, 1975) were available at city hall. Workshops sponsored in part by groups such as the League of Women Voters were performed in 1983 and 1986. Water bills also contained messages urging people to conserve. The basic approach here was to make the public aware of the dangers of running out of the most valuable resource.

Durham predicted the water levels in Lake Michie for July and August for a 23 MGD demand (no conservation). These values were revised for August and September at the end of July using demands of 23 MGD (no conservation) and 21 MGD (with conservation). The predicted levels and actual levels are shown in Figure 4.3 (Lake Michie elevation). During July the average demand was reduced from 23.1 MGD in June to 22.72 MGD in July due to implementation of moderate mandatory conservation on July 8. The results of mandatory conservation showed a 10% reduction in maximum daily demand. However, the average daily flow from July 9 to August 17 under mandatory conservation was 22.59 MGD. This represents only a 2.2% reduction in demand from June. The average demand for August 1-17 was 21.97 MGD representing a 5% reduction in demand from June. The actual reduction in demand is probably greater than these values shown, because we can assume that demand will increase as a drought worsens if no conservation is put into effect. Durham did not have a predicted value for demand under no conservation, so it is impossible to determine actual savings here. If we compare 1986 demand values to 1985 we see a 9.4% increase in demand for the four summer months (May - August). This is due partially to growth but mainly to the drought. The average demand for June, July, and August 1985 showed little variability (20.75, 20.67, & 20.91 MGD, respectively). If we considered this trend to be true when no conservation is put in effect, than we can assume that the given reductions in demand would be the actual values.

Lake Michie reached a low level on August 6, 1986, of 331.64 MSL or 9.36 feet below full. On August 20, 1986, Lake Michie went from 333' MSL to 341' MSL (Full) in a 24-hour period when 5.2" of rain fell from 8:00 am to 1:30 pm. On August 21 a proclamation by the Mayor returned Durham to stage 1 of the ordinance, because they were well above the 95% probability level of meeting a demand of 23 MGD.

Before the rains of August 20 fell, Durham had only a 100-day supply left in the reservoir at the current demand of approximately 23 MGD. At the beginning of August, it was predicted that by September Lake Michie would be at a record low and would have only a 75% probability of sustaining the current demand. If no rain had fallen, Durham was prepared to enter stage 4 by September. If the drought continued into the late fall, stage 5 would be entered and than possibly stage 6. Entering stage 6 could have had a severe economic impact on the City of Durham. Fortunately, the rains of August prevented this from happening. The drought did continue into the late fall after the rains, but the reservoir was not drawn down past a critical point again. The risk of not meeting demand is not as high in October as it is in August at the same lake level. Therefore, even though the lake level reached a low of 331 MSL in November, they still were at the 95% probability level of meeting demand.

Durham has a thorough method for data collection. Reservoir levels are read at least once a day by the plant operator and kept on computer at the plant. Stream flows are gauged on the Flat River, Eno River, and the Little River. During 1986, Eno River flows could be read by remote on the telephone while Flat River had to be read manually. Therefore, Eno River flows were converted to Flat River flows by the ratio of their drainage areas.

$$\text{Flat River flow (CFS)} = \text{Eno R. (CFS)} \times \frac{\text{D.A. Flat R. (Mi}^2\text{)}}{\text{D.A. Eno R. (Mi}^2\text{)}}$$

Today flows from the Flat River, Eno River, and Little River are all read daily by remote. Stage discharge curves are interpreted by the plant operator from curves obtained from the USGS.

An evaporation study was done on Lake Michie during the 1960's. From this study the estimation of evaporation is 1.5 MGD during summer months. This value is used for calculations of safe yield. Daily evaporation is determined by the change in lake level minus demand plus inflow.

**OWASA**

The Orange Water and Sewer Authority (OWASA) serves Chapel Hill and Carrboro with a total service population of 60,000 people. This includes the University of North Carolina (UNC) with approximately 21,000 students. During the summer months many students leave town reducing the service population. OWASA serves a customer base of 10,000 residential connections, 1,500 commercial connections, and the University of North Carolina, including North Carolina Memorial Hospital (NCMH). OWASA is presently served by University Lake with a capacity of 625 MG and a safe yield of 3.5 MGD. There is also a temporary impoundment on Cane Creek with a capacity of 190 MG and a safe yield of 2.3 MGD at 95% reliability. The permanent Cane Creek reservoir is scheduled for completion in 1990 with a capacity of 3 BG and a safe yield of 10 MGD. OWASA is served by one water treatment plant with a 10 MGD capacity and a maximum capacity of 14 MGD. The average daily demand in 1986 was 5.9 MGD with the max daily demand occurring on July 8 at 10.2 MGD.

OWASA's demand exceeded its safe yield several days during 1986 showing definite need to purchase water. Purchases were available through written intergovernmental agreements with Durham, Butner, and Hillsborough. The agreement with Durham allowed for purchase of up to 4 MGD of treated water. An agreement with Butner allowed for 3 MGD raw water to be treated by Durham and then purchased by OWASA. An agreement with Hillsborough provided approximately 1 MGD for the period of August 9 through September 12. OWASA also had a service area agreement with Durham to provide water in areas served by OWASA but under annexation by Durham. These agreements were essential to OWASA because without them they would have been in severe trouble of running out of water.

In 1977, Robert Blum developed a water conservation strategy for OWASA. This report was the only technical basis for drought management used for several years by OWASA. Blum proposed a drought management policy for OWASA at which different stages of conservation are put into effect depending on University Lake level (and volume remaining) and time of year. The levels are based on historical data of Morgan Creek flows from 1923-73 at University Lake dam. However, the risk of running out of water is not given. Therefore, the risk involved of using the lake levels by Blum was not known. In 1986, OWASA assumed they had an approximately 25% probability of running out of water if no purchases were made. Because Blum's report was based on 1977 demands, OWASA had to raise the original proposed lake levels for conservation to adhere to 1986 demands. Recommended levels are given in the current Chapel Hill ordinance. In 1987 OWASA also began using Moreau's model for managing their water system during droughts. Moreau's model is based on the risk of running out of water at a given demand and lake level (volume remaining) at a specific week in the year based on historical stream flows. This model is discussed earlier in this report.

Several methods were used by OWASA in 1986 to determine when they would enter voluntary and mandatory conservation measures in 1986. Besides specific lake levels, they had to use judgment and common sense in making decisions. This was based on past years experience as well as a statistical and analytical basis for risk. OWASA can afford to take a high risk because good regionalization agreements, allow them to purchase enough water to meet demand.

In making any decisions, the politics must be considered. The main objective here is not to run out of water. However, if at all possible you don't want to ask the public to restrict water use. OWASA also feels it cannot purchase until they are at least under voluntary restrictions. A community must show that it is making efforts to conserve its own supply before another community is willing to give up some of its own precious supply of water.

Final decisions are ultimately based on reservoir levels, risk levels, the ability to obtain water from emergency sources such as private quarries as well as the socio-economic and environmental impacts of entering or not entering any specific stage of the ordinance.

The area served by OWASA is not under the jurisdiction of one local government, but rather four. These include Chapel Hill, Carrboro, Orange County, and Durham County. This makes it very difficult to implement ordinances. The ordinance for Chapel Hill and Carrboro is based on the Blum report (see Appendix A.3). Orange County and Durham County have their own ordinances which are similar for areas served by OWASA. This makes for a very difficult situation for OWASA to enforce their operating regulations because they have no police power to enforce the ordinances. They can, however, turn off the water to a user if regulations are not being followed. Another problem faced by OWASA is having everyone under the same restrictions at the same time. It is difficult to get people to follow mandatory restrictions if other users on their system are not under any restrictions.

The people served by OWASA have been requested to reduce water use for many years. OWASA has entered voluntary conservation five times between 1977 and 1987 and mandatory conservation was put into effect 4 of those years. Public awareness of the situation is achieved by several methods which OWASA puts into effect year round, but most intensively during drought situations. Because OWASA's supply (safe yield = 6 MGD) is small compared to demand ( = 5.9 MGD in 1986), OWASA begins to feel the effects of a drought situation long before other communities. Some conservation measures taken over the last several years include the following. A level rate structure rather than a declining block structure was put into effect. Declining block structures tend to encourage waste rather than conservation because of the minimal cost of increased usage. A service charge as well as a usage charge for all water used was put into effect. In this manner, people are more concerned with all water usage rather than staying below a minimum level where additional use begins to cost more. Workshops for plumbers were set up encouraging and showing the benefits of using low flow devices. In 1977, OWASA urged a change in the plumbing code to mandate low flow fixtures on all new apartments and homes. A plan to detect leaks and rebuild the distribution system to minimize leakage was put into effect in 1983. Many apartment complexes in the Carrboro/Chapel Hill community were master metered. A study was done on individually metered apartments and it showed more people were aware of leaky toilets and faucets when they had to pay directly for the wasted water. OWASA also began a program to maintain meters and replace broken ones in 1983. This is helpful in determining where water is being used and the amount lost to leaky pipes in the system. These methods are all long-term water conservation measures used by OWASA.

Drought management may involve the use of voluntary and mandatory conservation measures that are effective in reducing the demand of water on a short-term basis. The public must be made aware of how they can save a considerable amount of water on a short-term basis until the drought passes.

As was the case for the other municipalities studied, the main source of alerting the public to the severe situation that OWASA faced in 1986 was through the use of newspapers, television, and radio public service announcements. The public was kept up to date as to what stage of conservation they were in and as to the laws governing each stage as set forth in the local ordinance. Educational programs were used in elementary through high schools. Educational workshops on water conservation were also performed through local civic clubs.

The University of North Carolina is a major user on the OWASA system and was therefore the target of intense water conservation awareness. Because many students are out of town during the summer months, they may not have been aware of the drought situation that the Chapel Hill community faced. "Officials of UNC wrote students due to report for the fall of

1986 semester to leave house plants and aquairiums at home and to come to Chapel Hill prepared to conserve water." (Christenson, 1986). The standard freshman orientation packet also included pamphlets on water conservation. Signs were put up all over campus. Restrooms contained signs reminding users to save and to report all leaks to the University. Conservation devices were also put into use on campus. OWASA also gave away low flow shower heads and shower restrictors. The educational programs gave a general feeling for the importance of saving water throughout the University and local community.

OWASA also used billing inserts (see Figure 4.4) and table tents (Figure 4.5) on water conservation at local restaurants. From all this intense flooding of the public with the need for water conservation, it would be difficult for anyone in the OWASA service area not to understand the need to minimize water usage.

OWASA is a difficult system to understand when determining average demand and drought demand because of the continually changing population due to UNC being in or out of session. Normally, the summer months have a much higher demand due to outdoor water use. However, OWASA serves fewer people during the summer because many students are out of town. One method for predicting reduction due to water conservation is to consider the demand during the early part of the drought (June), before any form of conservation is in effect, vs. that when voluntary and then mandatory conservation goes into effect.

In June 1986, average demand was 7.08 MGD. Voluntary conservation was put into effect on July 2. During the following n the Kitche d Laundry:

- Use sink disposal unit sparingly. Vegetable peelings and food scraps can be placed in the garbage can or on a compost heap in the garden.
- Scrape dishes, but don't prerinse. Soak pots and pans before washing. Fill wash and rinse basins with water and use a minimum amount of detergent.
- Don't leave the water running while you are rinsing dishes, washing vegetables, thawing frozen foods or getting a glass of water.
- Keep a bottle of cold drinking water in the refrigerator.
- Use your dishwasher and washing machine only when you have a full load. Avoid extra cycles and use the energy saving cycle.

ll Around the House:

- Recycle water from everyday activities (cooking, bathing, etc.) and use it to water houseplants, to scrub floors, or to bathe the family pet.
- Check for and repair leaks in pipes, faucets, couplings and hoses. Even small leaks can waste large amounts of water.
- Install water saving devices in your showers, faucets and toilets.

emember—it's easy to conserve water and ith just a little effort, these water saving tips an become water conservation habits.

**THANKS FOR YOUR HELP!**

r more information about water conservation, please contact:

OWASA
P.O. Box 366
Carrboro, N.C. 27510
968-4421

An Equal Opportunity Employer

**PLEASE READ CAREFULLY.**
**WATER USE RESTRICTIONS ARE NOW IN EFFECT.**

Orange Water and Sewer Authority
Post Office Box 366
Carrboro, North Carolina 27510

Bulk Rate
U.S. POSTAGE
PAID
Carrboro, N.C.
27510
Permit No. 27

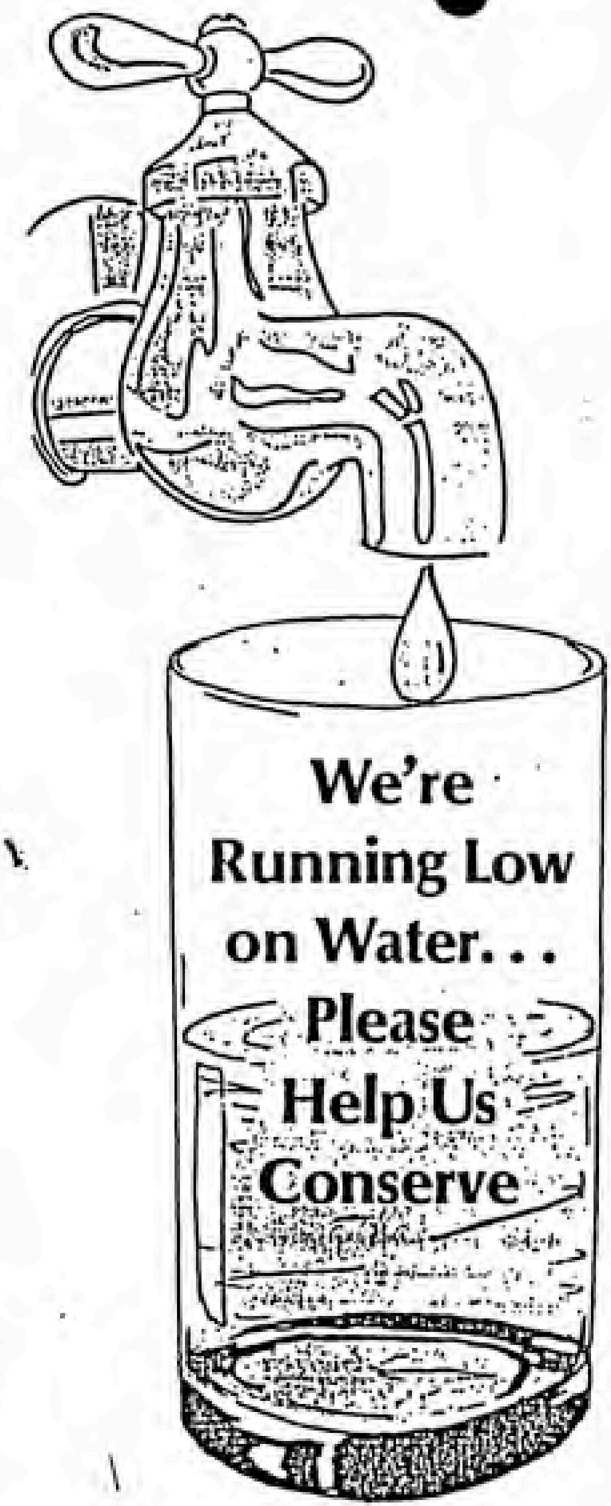



Figure 4.4

(his summer temperatures have been high ınd the amount of rainfall we have received ıas been far below normal. In fact, the current lrought is the worst to occur in the area in ›ver 100 years. As a result our community's vater supply is being used up rapidly and Mandatory Restrictions on water use are now n effect.

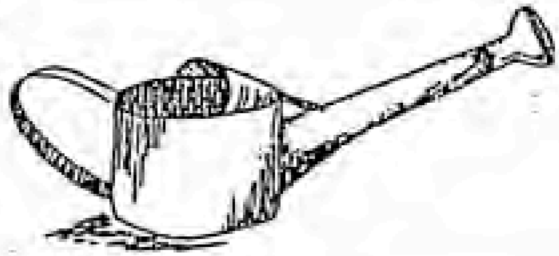
Nater use has dropped significantly thanks to he cooperation of customers, who have esponded to the request to conserve water. However October, November and December ıre historically the driest months of the year, ınd, if the current weather pattern continues, ıur community will face a very serious water hortage in the coming months. For this eason, we are asking that you reduce water ısage even further, while we investigate ılternative water supply sources. This will help o conserve as much as possible of our present vater supply.

## STAGE III: WATER SHORTAGE DANGER CONDITION EXISTS MANDATORY WATER USE RESTRICTIONS NOW IN EFFECT

'he level of water in University Lake, the :ommunity's primary water supply source, has lropped to more than 54 inches below full. lecause of the seriousness of the current vater shortage, moderate mandatory estrictions on the use of water are now in :ffect in our community. These restrictions nake it unlawful to use water from the public vater system supplied by OWASA to:

1. Water or sprinkle any lawn.
2. Water any vegetable garden or ornamental shrubs except during the hours of 6:00 am to 9:00 am on Saturday. Such watering is only to be done by hand-held hose or drip irrigation.
3. Make any non-essential use of water for commercial or public use. Alternatives such as disposable plates and utensils are encouraged in area restaurants.
4. Fill newly constructed swimming and/or wading pools or refill swimming and/or wading pools which have been drained. A minimal amount of water may be added to maintain continued operation of pools which are in operation at the time the provisions of a Stage II WARNING are placed into effect.
5. Operate water-cooled air conditioners or other equipment that does not recycle cooling water, except when health and safety are adversely affected.
6. Wash automobiles, trucks, trailers, boats, airplanes or any other type of mobile equipment, including commercial washing.
7. Wash down outside areas such as streets, driveways, service station aprons, parking lots, office buildings, exteriors of existing or newly constructed homes or apartments, sidewalks, patios, or other similar purposes.
8. Operate or introduce water into any ornamental fountain pool or pond or other structure making similar use of water.
9. Serve drinking water in restaurants, cafeterias or other food establishments, except upon request.
10. Use water from public or private fire hydrants for any purpose other than fire suppression or other public emergency.
11. Use water for dust control or compaction.
12. Use water for any unnecessary purpose or intentionally waste water.

The owner or occupant of any land or building that receives water from OWASA and that also utilizes water from a well or supply other than OWASA shall post and maintain in a prominent place a sign giving public notice that a well or other source of supply is being used.



In addition to the above restrictions, here are some further suggestions for saving water during the current water shortage and throughout the year.

In the Bathroom:

- Take short showers and run the water only to wet down and rinse off.
- If you take a bath in the tub, plug the drain before you run water. Don't fill the bathtub as full as you might normally do and bathe small children together.
- Flush the toilet only when necessary. Install a water-saving displacement device, such as a weighted plastic jug full of water, in your toilet tank. Be sure that the device does not interfere with operating parts of the toilet.
- Don't run the water continuously while you are brushing your teeth or shaving. Use a cup of water to rinse your toothbrush and plug the sink and run a small amount of water to rinse your razor.
- Install a faucet aerator or low-flow shower head to reduce the amount of water used.

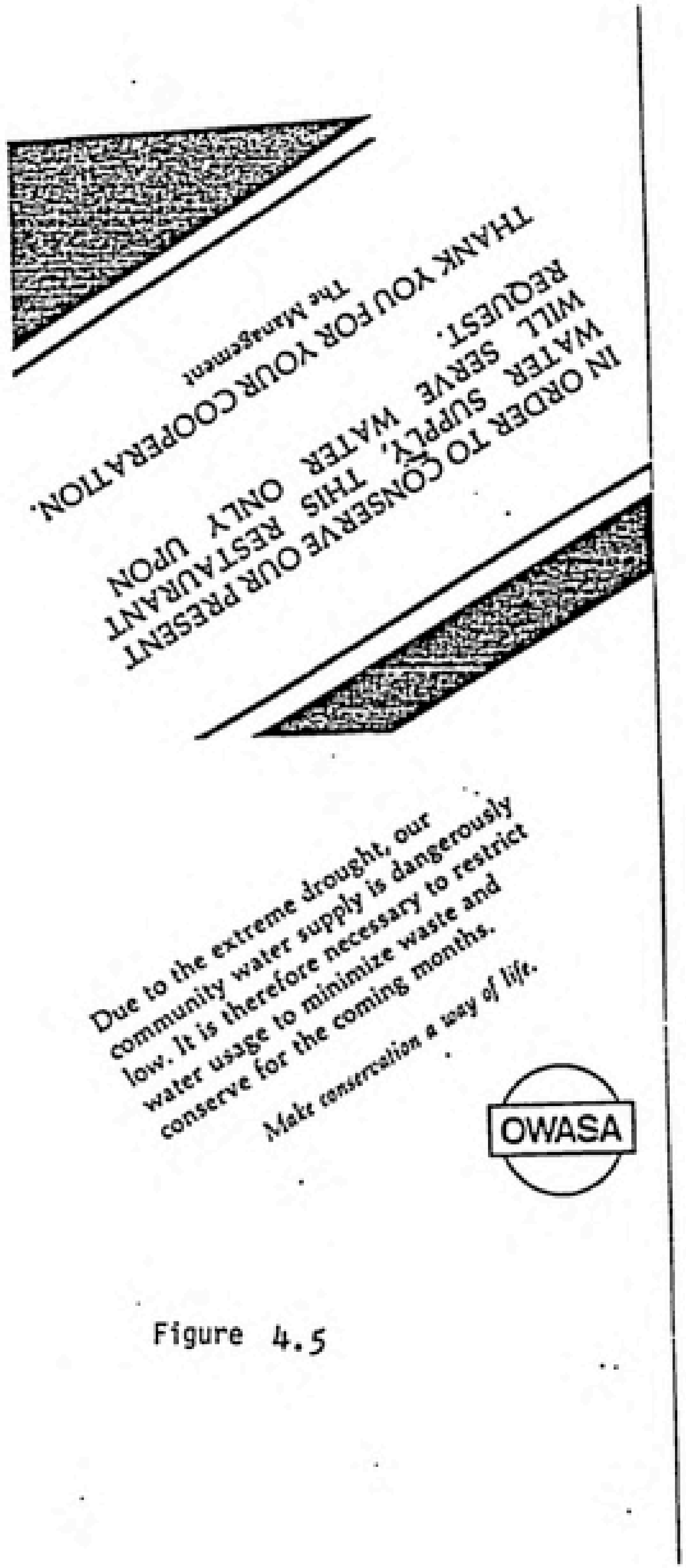

IN ORDER TO CONSERVE OUR PRESENT
WATER SUPPLY, THIS RESTAURANT
WILL SERVE WATER ONLY UPON
REQUEST.
THANK YOU FOR YOUR COOPERATION.
The Management
Due to the extreme drought, our community water supply is dangerously low. It is therefore necessary to restrict water usage to minimize waste and conserve for the coming months.
Make conservation a way of life.
OWASA

Figure 4.5

week, demand was reduced 4.6% to 6.75 MGD. Moderate mandatory conservation went into effect July 9. Mandatory conservation remained in effect until September 3 when OWASA returned to voluntary restrictions. The drought continued throughout September and stage II (moderage mandatory restrictions) were reentered on October 16. OWASA again returned to voluntary restrictions on December 8. All restrictions were finally rescinded on December 22, 1986.

The savings due to conservation is difficult to determine. During the years 1975 through 1987, the mean demand for June, July, August, and October was approximately 5.75 MGD. The mean for September over the same time span was 6.28 MGD. This is probably due to the return of students to UNC. During a drought, water use is expected to increase as the dry period progresses, if no conservation is put into effect. OWASA claimed up to 25% reduction in demand due to mandatory conservation. They did not provide any data verifying this. Shea (1988) showed a 4.5% reduction in demand during the first week of July when voluntary conservation was in effect. During the period of mandatory conservation, from July 9 through September 2, demand decreased each week. During the month of July demand decreased to 6.07 MGD a 14% reduction in use from June demand. During August, under mandatory restrictions demand was 5.9 MGD a 17% reduction from June demand. This could be due to factors other than conservation. Rainfall during August was 7.52 inches compared to the average for the past 97 years of 5.03 inches. Most of the rain occurred late in August. While this helped reduce demand, it did little to help the dwindling supply.

OWASA was able to return to stage I restrictions on September 3. Voluntary restrictions appear to be very effective because September demand was only 6.8 MGD. If we allow for a 1 MGD increase due to returning students (Blum, 1977) this represents an 18% decrease in demand from June. This is somewhat surprising because September rainfall was only 0.8 inches.

How much water OWASA conserved by implementing conservation is unclear. The assumption is that usage may have been between 7.5 and 8.0 MGD for the summer months. This could have severely depleted the system if alternative sources were not available.

OWASA keeps daily updates of the system by monitoring reservoir levels, evaporation data, and streamflows.

Reservoir levels are read on a daily basis by OWASA personnel at University Lake, Cane Creek, and Stone Quary reservoir. Stream flows are not measured on Morgan Creek. Stream flows for Morgan Creek are correlated from stream flows on the Eno River and Cane Creek.

Evaporation data are measured by the National Weather Service, weather station in Chapel Hill. Daily records are kept for evaporation. OWASA keeps on file records for rainfall, temperature, and evaporation dating back to 1936 (1855 for rain).

Demand is estimated by keeping a three-week rolling average. This is compared to previous averages in the current year and past years. Judgment is used to predict demand in the upcoming months.

**Demand Reduction**

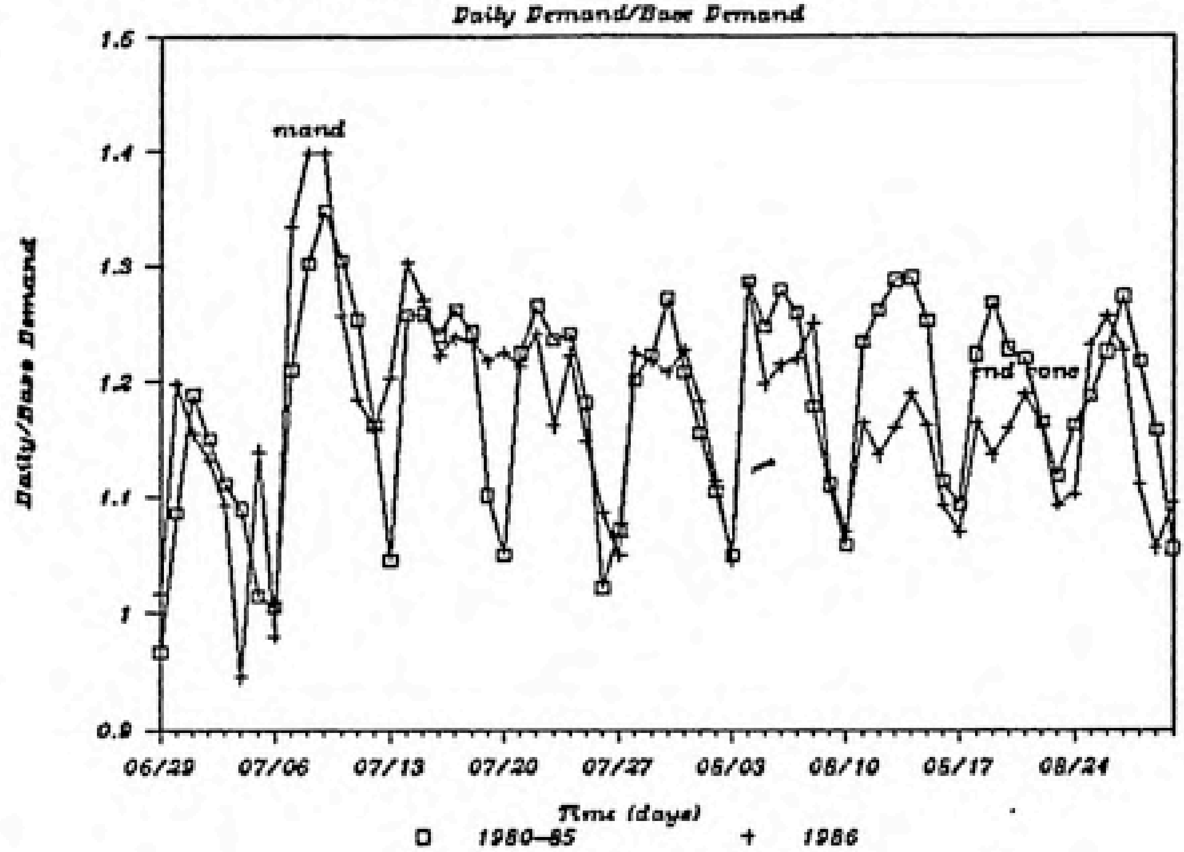
Demands for water can vary a great deal over the period of a drought. Variability in demand during drought periods is often due to a day of the week effect, rainfall and implementation of conservation or other demand reduction techniques as well as temperature, pricing, holidays and industrial plant closings.

This section examines the reduction in average weekly and daily demand when conservation was implemented by Durham and Greensboro during the 1986 drought. It is improtant for a city to determine how effective the use of voluntary or mandatory conservation are in reducing demand during a drought. Unfortunately a straightforward calculation of the percent change in water use from before conservation to during conservation may show a change that is not due entirely to conservation.

The factors to consider include conservation, rainfall, day of week, week of year, month of year, temperature and pricing techniques. Week of year and month of year are neglected because conservation was implemented over the months of July and August when average demand varies very little. Temperature during this period also varies very little and is not considered. Neither of the utilities involved implemented special pricing techniques so pricing was not considered. Day of week was shown to be a significant source of variation by Moreau(1984) with 27% of variance about baseload attributable to day-of-week for Durham and 29% for Greensboro. The variation in daily demand can be seen in Figs.4.6a & 4.8a. To eliminate day-of-week effect, weekly averages were also calculated and compared.

Figure 4.6

## DURHAM-EFFECTS OF CONSERVATION




## DURHAM-1986 PRECIPITATION

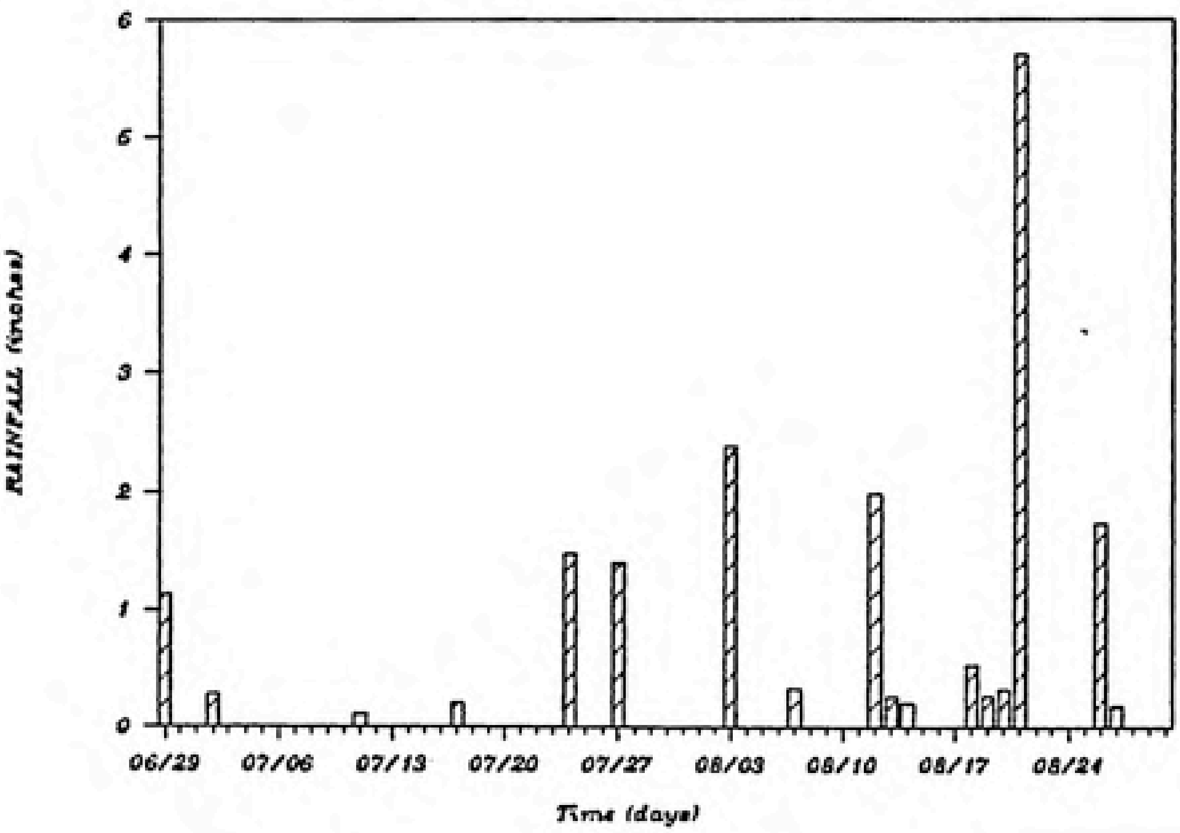
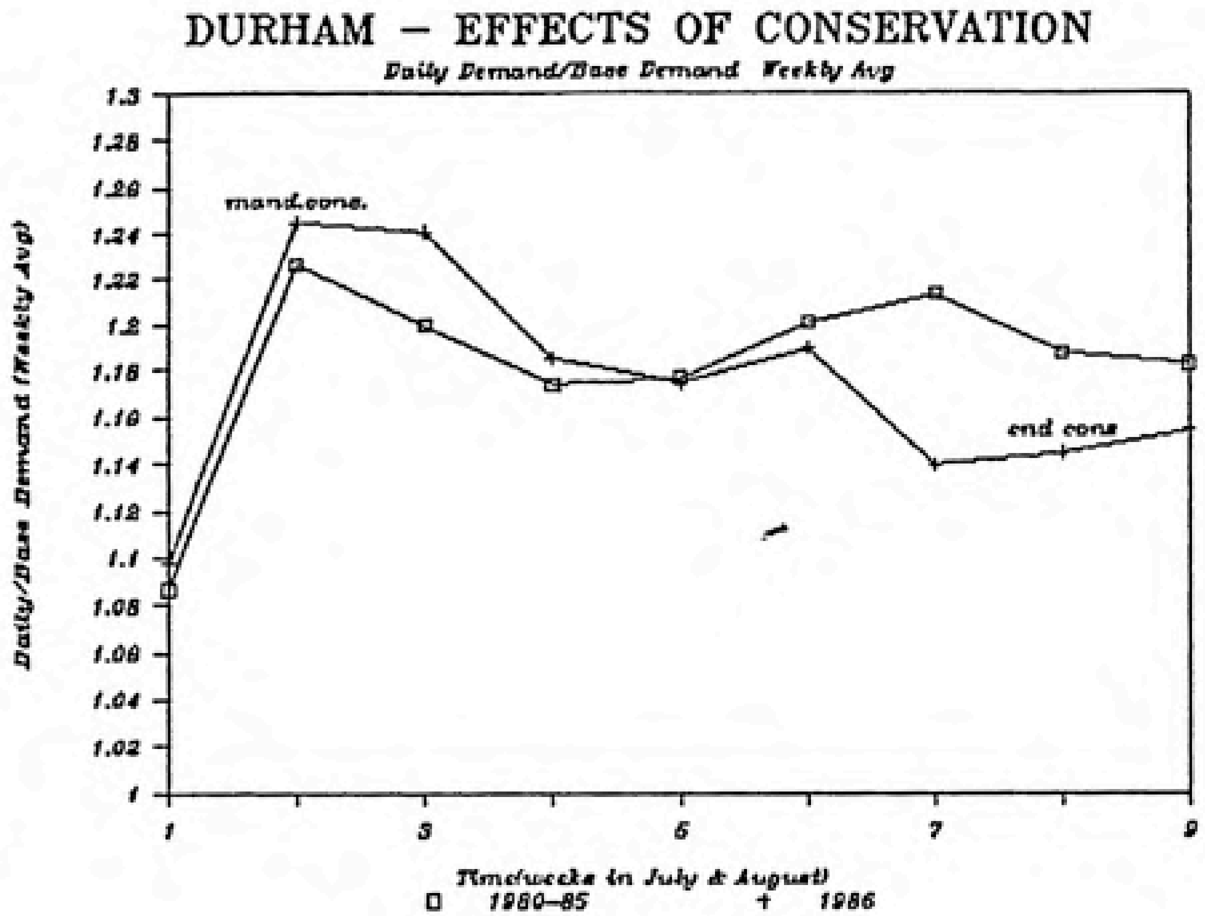


Figure 4.7


DURHAM - EFFECTS OF CONSERVATION
Daily Demand/Base Demand Weekly Avg
Daily/Base Demand (Weekly Avg)
mand.cons.
end cons
Time(weeks in July & August)
1980-85
1986

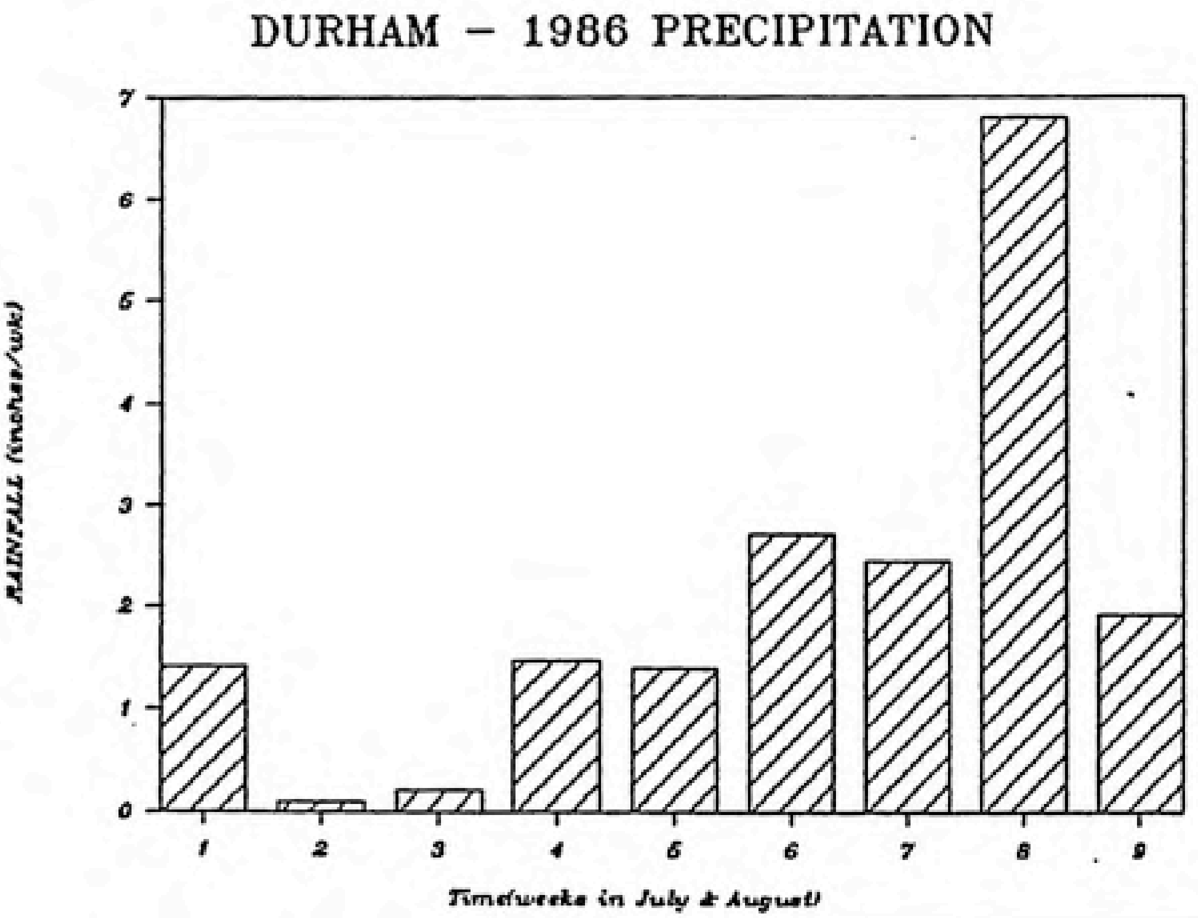
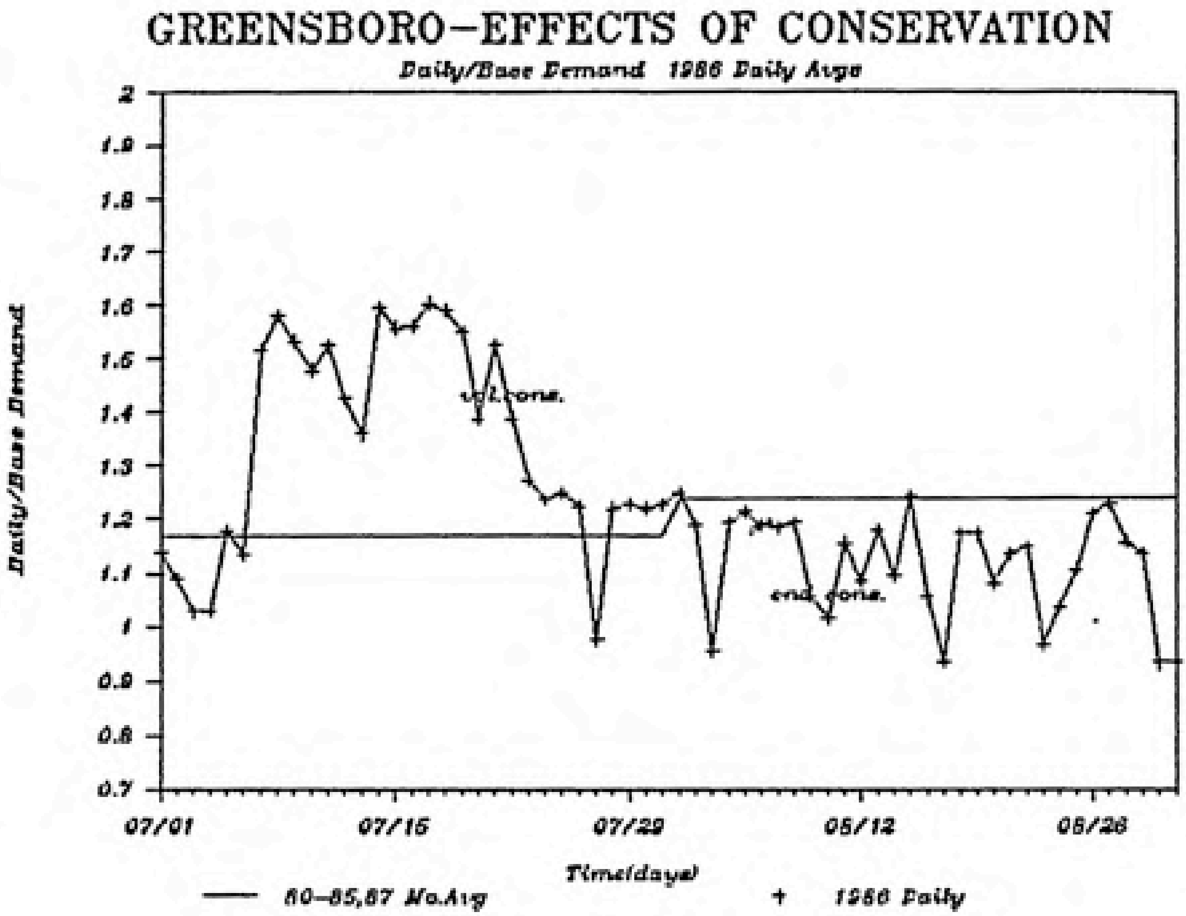

DURHAM - 1986 PRECIPITATION
RAINFALL (inches/wk)
Time(weeks in July & August)

Figure 4.8


GREENSBORO-EFFECTS OF CONSERVATION
Daily/Base Demand 1986 Daily Avgs
Daily/Base Demand
vol. cons.
end cons.
07/01
07/15
07/29
08/12
08/26
Time(days)
80-85,87 Mo.Avg
+ 1986 Daily

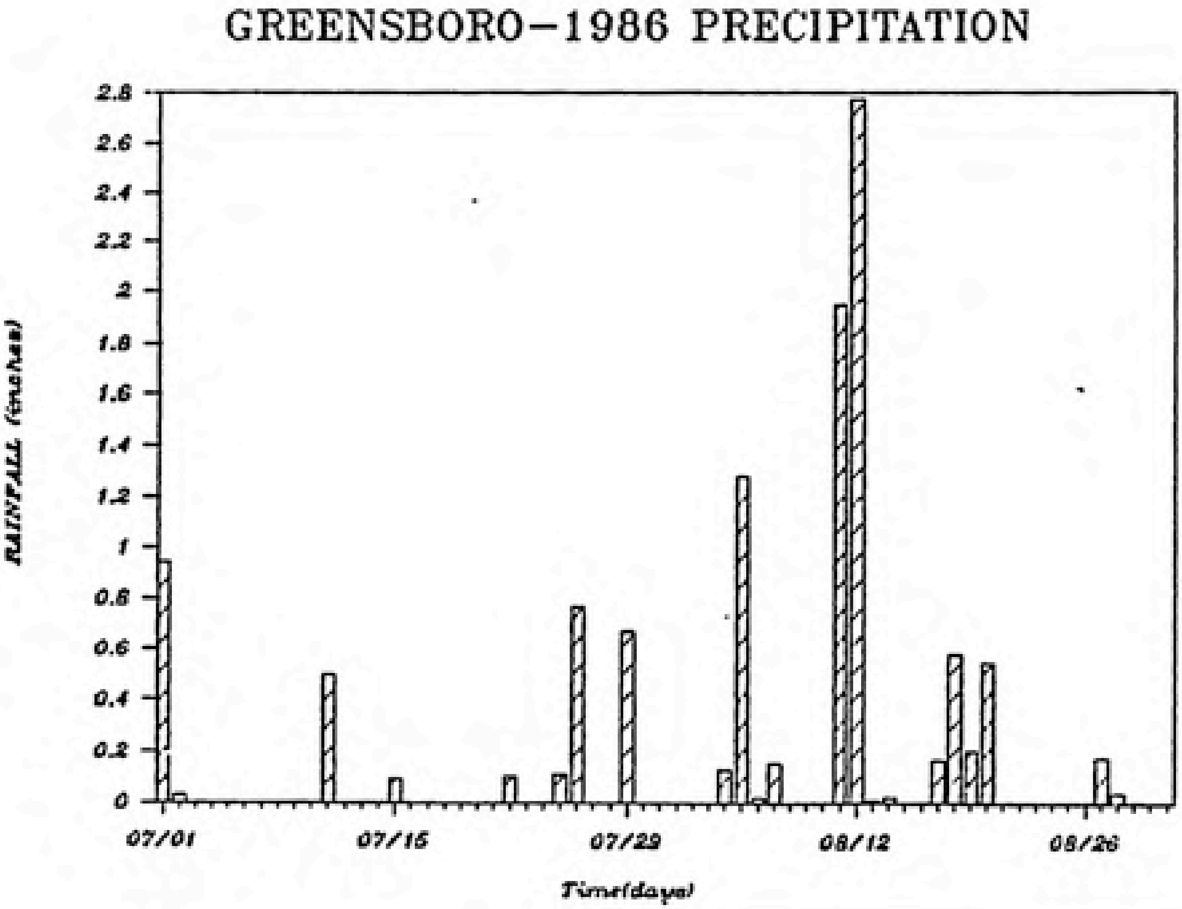
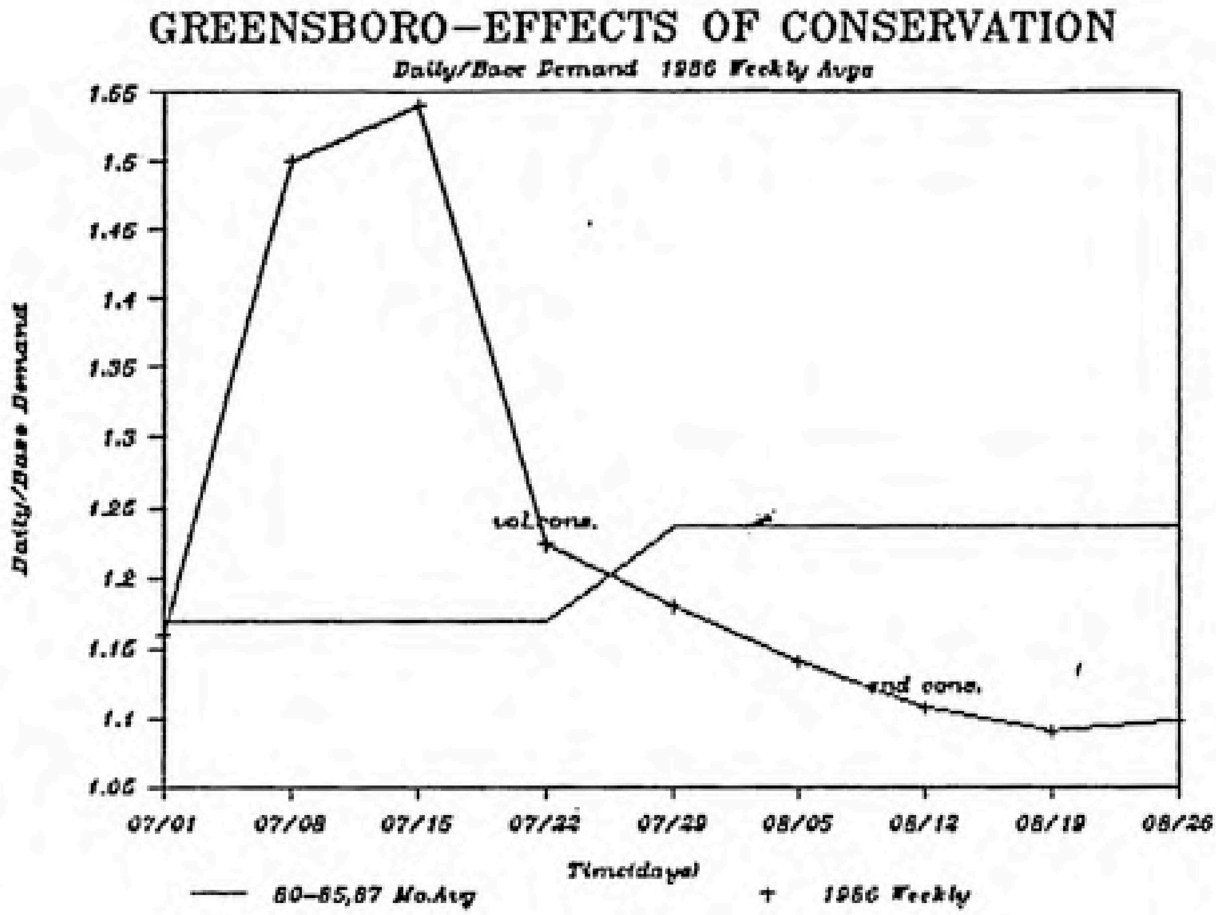
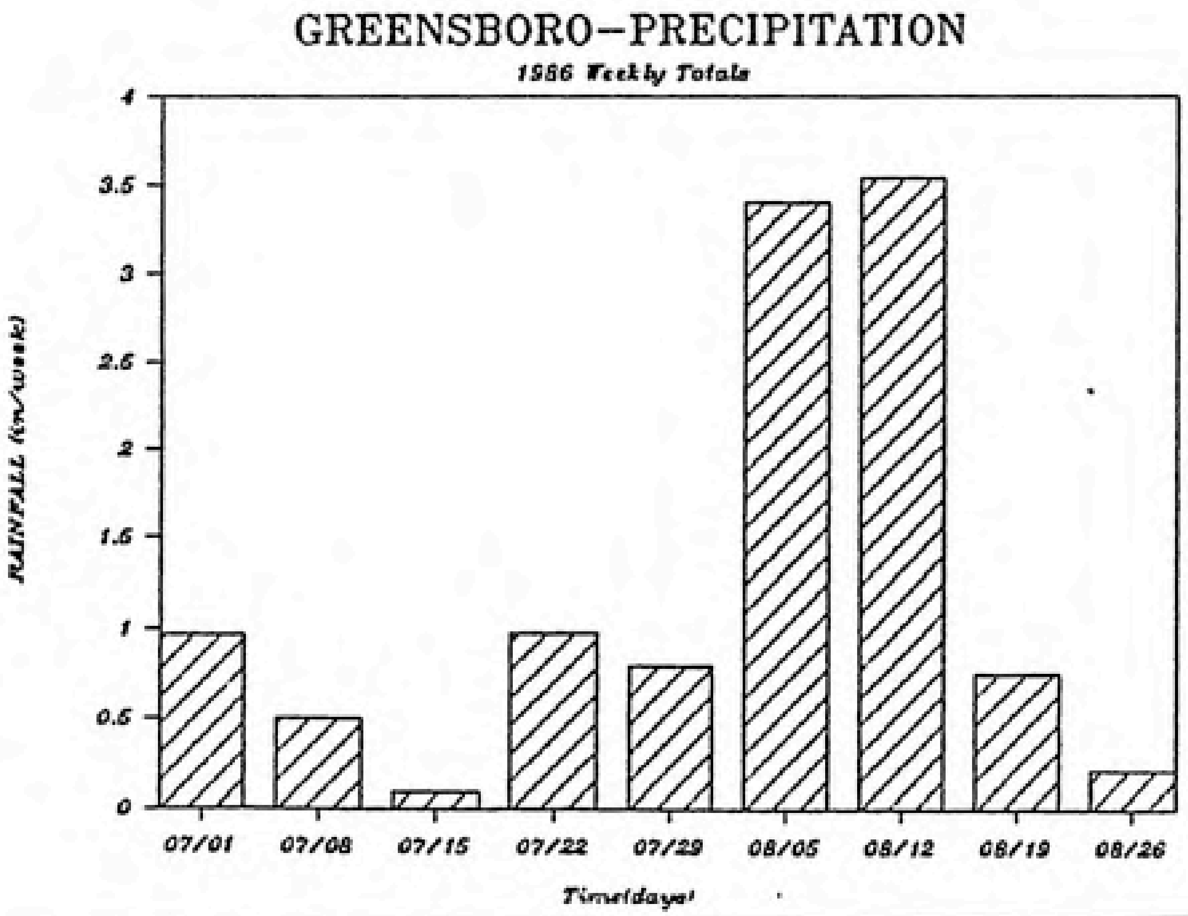

GREENSBORO-1986 PRECIPITATION
RAINFALL (inches)
07/01
07/15
07/29
08/12
08/26
Time(days)

Figure 4.9


GREENSBORO—EFFECTS OF CONSERVATION
Daily/Base Demand 1986 Weekly Avgs
Daily/Base Demand
1.55
1.5
1.45
1.4
1.35
1.3
1.25
1.2
1.15
1.1
1.05
vol. cons.
end cons.
07/01
07/08
07/15
07/22
07/29
08/05
08/12
08/19
08/26
Time(days)
60-65,67 Mo.Avg
+ 1986 Weekly


GREENSBORO—PRECIPITATION
1986 Weekly Totals
RAINFALL (in/week)
4
3.5
3
2.5
2
1.5
1
0.5
0
07/01
07/08
07/15
07/22
07/29
08/05
08/12
08/19
08/26
Time(days)

For all cases 1986 demand was plotted along with the mean for other years in the 1980's. To eliminate a yearly effect a ratio of daily demand to year baseload demand was used. The baseload is the average for the months of Jan.-April and Nov.-Dec. and is associated with indoor water use. Another important factor to consider is that during a drought demand increases as people substitute system water for precipitation that normally takes care of many outdoor uses. Therefore a reduction in demand may occur during conservation even though demand is still above the average demand for that time of year.

Calculations of the percent reduction in demand after conservation was implemented and possible factors for this reduction are discussed below.

**Durham**

The months of July and August 1986 showed a variation in average weekly demand of 8% from the week when mandatory conservation began until the week, before it ended. The maximum variation during this period for the years 1980-85 was only 5%. A week by week analysis under mandatory conservation follows. During the second week of conservation no demand reduction was noticed and only 0.2 inches of rain fell. During the third week demand was reduced by 4%, but 1.47 inches of rain fell all in one day. Demand decreased another 2% the following week when 1.4 inches of rain fell. The following week demand increased by 2% while 2.7 inches of rain fell. Demand again fell by 3% during the sixth week of conservation, with the help of 2.44 inches of precipitation. Demand remained at this level and conservation was lifted when 6.8 inches of rain fell from August 18-21. If we look at daily variation in demand, it should be noted that demand on Saturdays under conservation was actually higher than would be expected because lawn watering was permitted on Saturdays. The maximum reduction in 7-day average daily demand was 8%, during mandatory conservation, however demand did not begin to decline until significant rainfall occurred. A total of 13.84 inches of rain fell in August which is 9.07 inches more than is normally expected. Therefore we would probably attribute much of this reduction to rainfall.

**Greensboro**

The city of Greensboro's demand during the second and third week of July was as much as 32% above normal expected use for July (based on 1980-85,87 monthly average). Greensboro implemented voluntary conservation on July 22. A reduction in demand was shown almost immediately. Demand was reduced 19% the first week while 1" of rain fell over 4 days. The next week demand was reduced by 24% over pre-conservation use with the aid of 0.8 inches of rain during 2 days. Demand continued to decline the following week and a total reduction of 26% was shown with 3.4 inches of rain falling. Ray Shaw (1988) credited the reduction to a combination of conservation, cloud cover, intermitant rain showers and a lack of high winds. It is difficult to determine how much of this reduction is due to conservation, but it was definitely shown to be effective.

**Conclusions**

Decision making during droughts is based mainly on engineering judgment based on similar circumstances in previous years. This could have resulted in actions that were overly risk averse.

Durham seemed to have the most sound technical basis for decision making. At any time during the year they can tell what is the probability of not meeting a given demand they face. One problem they face is that they do not know the social or economic impacts of not sustaining a given yield.

Accurate predictions of demand with and without conservation are difficult to make. All utilities predicted drought demand based on past experience. A model to predict demand based on current climatological conditions would be helpful in determining the consequences of water conservation. This is important in finding the reduction in risk due to implementing a policy.

The importance of having set criteria is to know when during the year a specific decision on operating your system should be made. In this manner, decisions will not be made too soon or too late.

OWASA and Durham show that regional agreements to supply water are an extremely important part of drought management. OWASA's supply has historically been too small to meet increased demand during hot, dry summer months. Without the ability to purchase water, the well may have run dry on OWASA in 1986.

The objective of building a water supply should be to meet demand for all years except a very small percentage depending on the risk a community is willing to face and the feasibilty of the project. A drought management policy should allow a community to make it through a drought through the implementation of supply augmentation and demand reduction measures. A drought management policy should result in people feeling minimal effects of the drought. The towns of Chapel Hill and Carrboro have felt more than their share of drought situations over the past several years. Until Cane Creek reservoir is completed this could happen again.

Politics play an important role in drought management. Who will take the blame for running out of water? How willing are people to be under water restrictions? How much will people pay for alternative sources? Is a community willing to give up its precious water supply to another community? What are the economic and environmental impacts of increasing the size of your water supply to prevent future conservation measures? These are questions a utility director must answer to help in decision making.

In making decisions, all alternatives should be considered. Utilities should evaluate all alternative sources such as private wells or quarries, drilling new wells, using abandoned wells, or tapping a nearby river. Purchasing water should be considered ahead of voluntary and mandatory conservation if economically feasible and socially acceptable.

The size of one's supply resulted in the largest variety of management policies and responses. High Point's large supply of water allowed them to sit back and allow people to use as much water as possible. Greensboro's supply is at the size where they normally do not have a problem. In 1986, this resulted in them not being well prepared to face a long-term drought. They were fortunate enough to receive an abundant amount of rain before the problem worsened to a state of emergency. Durham's supply was enough that they were prepared to make quick decisions or the status of their system. OWASA's limited supply has resulted in them being affected by several droughts. In this manner, they were prepared to make decisions on managing their system.

Water is essential to our well being, yet when it's in abundance, we don't give it a second throught. Managing a system should allow consumers to use water as needed without having adverse effects on the community in the long run.

It is suggested that utilities adopt a drought management policy that will help them make decisions based on the risk involved with their decisions and the probabilities of the outcomes associated with alternative management options.

Purchasing water should be considered as an alternative to conservation where regionalization of supplies is feasible and available. Public awareness is an important part of both voluntary and mandatory conservation. A good public attitude can result in significant reductions in demand. Long-term conservation techniques can be implemented to extend the useful life of a supply (reduce demand below safe yield).

*Demand data was collected from the city of Greensboro and the city of Durham.
*Precipitation data from NOAA (June - September,1986)

## CONCLUSIONS AND RECOMMENDATIONS

Water utilities have been operated in several different ways in order to manage the many problems faced by a utility. Drought is a major problem that seems to be faced more often today due to increasing population, increasing demand and insufficient supplies.

Reservoirs have commonly been designed to meet the demand for water in all but a 1 in 100 year drought. Drought management techniques can then be used to get a community through a drought. However, it appears utility directors often are not prepared to implement a drought management policy.

Drought policy on the federal level has been treated as crisis management rather than risk management. Current policy in the U. S. does not encourage the adaption of efficient management practices to ensure against abnormal risk.

Risk is becoming more common in the management of public water supplies. Operating policies have been developed that use risk tables and graphs to aid water managers in decision making during droughts. These are useful in real-time use because they are developed for ease of use by utility directors and allow them to choose an acceptable risk they are willing to face.

Several authors have developed resevoir management and operations policies. Presently, however, there is still a gap between theory and application when it comes to real time reservoir operation. Many of these models are based on economic optimization, and often disregard the reliability of the system under drought conditions. Their use by public utility directors has been limited to this point often because the water manager has not participated in developing the model or the models are not applicable to complex systems. Other drawbacks to these models for real-time use is they often do not consider uncertainty of future inflows.

Many alternative demand and supply management techniques are available. All alternatives should be considered to determine what is technically, economically, socially or legally feasible. Feasible alternatives should than be considered in a cost-benefit analysis to determine the best available combination of options.

The drought of 1986 had a definite impact on several municipalities in the Southeast. Of the 573 utilities that serve 10,000 or more people 40% called for some form of conservation in 1986. One problem faced by a large number of utilities was that they had no ordinace or other written policy for operating their water supply under drought conditions. Only 39% had any ordinance for drought management policies in 1986. Only 18% of systems surveyed had any form of technical report to support the basis for such a policy. One-third of those utilities surveyed had an agreement with another utility to provide a supplementary supply of water.

The states of North Carolina, South Carolina and Georgia faced the most severe drought conditions in 1986. The extent to which individual utilities were affected varied with how prepared they were to manage their systems under these conditions. Presently, Georgia, Florida and South Carolina would be best prepared to face another drought. This is due to statewide drought response acts and water management districts.

The four utilities studied showed a variety of approaches to drought management. The size of one's supply relative to demand resulted in the largest variety of management policies and responses. High Point's large supply allowed them to sit back and allow people to use as much water as possible. Greensboro's supply is large enough that they normally do not have a problem. In 1986, this resulted in them not being well prepared to face a long-term drought. Durham was at a point where peak demand exceeded safe yield of the system. However, they were prepared to make quick decisions on the status of their system. A binding ordinance allowed them to implement mandatory conservation measures and enforce these. OWASA's summer demand often exceeds its safe yield causing them to be affected by several droughts. The experience of dealing with past dry years allowed them to make decisions on managing their system.

Decision making during droughts is based mainly on engineering judgment and experience incurred from similar circumstances in previous years. Durham used a combination of judgment and risk tables. The levels they used follow:

| Stage | Prob of sustaining given demand |
|---|---|
| Voluntary Conservation | $\leq$90% |
| Moderate Manatory | $\leq$80% |
| Mandatory | $\leq$75% |

OWASA used lake levels stated in their ordinance. These were used in combination with judgment. In 1988 OWASA is using a combination of judgment and risk tables developed by

Moreau (1987). Greensboro used a capacity use curve and engineering judgment.

Standard references also give very little stated criteria for decision making. Fair, Geyer and Okun (1971) suggest designing a reservoir for a 1% (1 in 100 yr. drought) chance of not meeting demand or for a 1 in 20 year drought with a 25% reserve. They suggest the level at which water use reduction techniques should be implemented is between 20 and 50% of total water stored. McGarry (1985) stated allowable risk levels for the Washington Metropolitan Area.

Probability of Occurence in Any Year

| Stage | Period of Implementation | |
|---|---|---|
| | <30 days | >30 days |
| I- Restricting Outside Use | 8% | 5% |
| II- Air Conditioning & Swimming Pool Restrictions | 3% | 2% |
| III- A Increasing Severity | 1% | 1% |
| III- B " " | 1% | 1% |
| III- C " " | 1% | 1% |

Moreau (1988B) gives examples of acceptable risk levels that may be chosen, but does not specify any specific allowable risk. It would seem that no one is willing to state one specific criteria for decision making because of the individuality of systems, the variety of drought occurrences and politics involved in choosing any level of risk.

Another criterion used for decision making by several South Carolina communities along with engineering judgment and experience is the Palmer Drought Severity Index. According to Tom Heddinghaus (June 6, 1988) of the Climate Analysis Center of the National Meteorological Center the Palmer Index gives a good overall picture of the extent and duration of a drought. However, it says nothing about an individual utilities supply and is therefore of limited use to water managers.

The exact reductions due to conservation were difficult to determine. Greensboro showed a 26% reduction under voluntary conservation but was aided by above average rainfall, and cloud cover. Durham was able to reduce max daily demand by 10% under mandatory conservation. They also showed a reduction of up to 8% from demand when conservation was implemented to demand when conservation was recinded. However, the reduction in demand began to occur only after significant rainfall occurred.

OWASA and Durham show that regional agreements to supply water are an extremely important part of drought management. Without these agreements, OWASA may have had to go to rationing to prevent running out of water.

**Recommendations**

In designing a drought management policy, politics will play an important role. Utilities should try to get the help of public opinion to base acceptable levels of risk on and the drought management alternatives that are available. Questions that need to be asked include the following: How willing are people to be under water restrictions? How much will people pay for alternative sources? Is a community willing to give up its precious water supply to another community? What are the economic and environmental impacts of increasing the size of your water supply to prevent future conservation measures?

It is extremely important to consider all economic and social impacts of the alternatives available. If possible a thorough benefit/cost analysis should be done to determine possible impacts of making decisions under drought conditions.

A continuation of the work done in the case studies of this report should be done by surveying all the utilities studied in the survey section of this report who had drought management policies. The findings from this survey should be analyzed. These findings should be evaluated with attention to the extent and readiness of interlocal agreements, the appropriateness and level of refinement of the criteria used for decision making, including their capacity to predict the probabilities of outcomes associated with alternative management options. These should be helpful in developing models to aid water managers in the operation of their systems.

REFERENCES


Ameen, J.J., Community Water Systems,Source Book, Technical Proceedings, High Point, NC, 1964.

American Water Works Association "Water Conservation at Home... Why to - Where to - How to -", AWWA, 1975.

"An Age of Economics and Stilled Water Projects," New York Times, August 9, 1981.

Askew, A. J., "Chance-Constrained Dynamic Programming and the Optimization of Water Resource Systems," WRR, Vol. 10, No. 6, pp. 1099-1106, Dec. 1974.

______, "Optimum Reservoir Operating Policies and the Imposition of a Reliability Constrant," WRR, Vol. 10, No. 1, pp. 51-56, Feb. 1974.

Bowmann, D.D., J. J. Boland and J. H. Sims, "Water Conservation: The Struggle Over Definition," WRR, Vol. 20, No. 4, pp. 428-434, Apr. 1984.

Billingsley, E., Executive Director, Orange Water and Sewer Authority, personal communication, May 13, 1988.

Blackwelder, B. and P. Carlson, "Survey of Water Conservation Programs in the Fifty States: Model Water Conservation Program for the Nation," Environmental Policy Institute, Aug. 1982.

Blum, R. G., "Water Conservation Strategy for the Orange Water and Sewer Authority (OWASA) Service Area, Chapel Hill-Carrboro, North Carolina," Master's Technical Report, UNC-Chapel Hill, 1977.

Charleston Commissioners of Public Works, Water Conservation Plan.

Christenson, M. F., "The Drought of 1986 - Municipal Water Shortages," Southern City - N. C. League of Municipalities July/August 1986.

City of Griffin Water and Sewer Dept. Water Conservation Plan for the City of Griffin 1987.

Clark,J.W., W. Viessman Jr., and M.J. Hammer, Water Supply and Pollution Control, 3rd ed., Harper and Row, New York, 1977

Clyde, E. W., "Legal and Institutional Aspects of Drought Management," From Drought Management and Its Impact. . . 1986.

Denny, L. M. and T. R. Heddinghaus, The Drought Severity (Long-Term, Palmer) Index, "Weekly Weather and Crop Bulletin, Vol. 74, No. 16, April 21, 1987.

Dorfman, R., "Mathematical Models: The Multi-structure Approach," in Design of Water Resources Systems, edited by A. Maass, Harvard Univrsity Press, Cambridge, MA, 1962.

Dracup, J. A., "Causes and Occurrence of Drought," From Drought Management and Its Impact. . ., 1986

Drought Management and its Impact on Public Water Systems, (DRAIIOPWS) Report on a Colloquim sponsored by Water Science and Technology Board, Sept. 5, 1985, National Academy Press, Washington, DC, 1986.

Dziegiedewski, B., "Drought Management Options," From Drought Managment and Its Impace. . ., 1986.

Eastman, J., and C. Revelle, "The Linear Decision Rule in Reservoir Management and Design, 3, Direct Capacity Determination and Intra-season Constraints," Wate Resources Res., Vol. 9, No. 1, pp. 29-43, Feb. 1973.

Fair, Geyer and Okun, Elements of Water Supply and Wastewater Disposal, 2nd ed., John Wiley and Sons, Inc., New York, 1971.

Fuscoe, W. "Regional Water Management" Master's Technical Report, UNC-Chapel Hill, 1986.

Georgia Department of Natural Resources Georgia Water Conservation Guidebook, 1981.

Greene, J. "The Politics of Drought; Was Last Summer's Crippling Drought Preventable? Will the Next One Be?," Southern Magazine,April 1987.

Grigg, N. S., Urban Water Infrastructure, John Wiley & Sons, 1986.

Gundelach, J. and C. Revelle, "Linear Decision Rule in Reservoir Management and Design, 5: A General Algorithm," Water Resources Res., Vol. 11, No. 2, pp. 204-207, Apr. 1975.

Heddinghaus, Thomas R., of National Meteorological Center - Climate Analysis Center, personal communication June 5, 1988.

Houck, M. H., and J. L. Cohon, "Sequential Explicitly Stochastic Linear Programming Models: A Proposal Method for Design and Management of Multipurpose Reservoir Systems," Water Resources Res., Vol. 14, No. 2, pp. 161-169, Apr. 1978.

Houck, M. H. and B. Datta, "Performance Evaluation of a Stochastic Optimization Model for Reservoir Design and Management with Explicit Reliability Criteria," WRR, Vol. 17, No. 4, pp. 827-832, Aug. 1981.

Karamouz, M. and M. H. Houck, "Comparison of Stochastic and Deterministic Dynamic Programming for Reservoir Operating Rule Generation," Water Resources Bull., AWRA, Vol. 23, No. 1, pp. 1-9, Feb. 1987.

Labadie, J. W., D. A. Bode, and A. M. Pineda, "Network Model for Decision-Support in Municipal Raw Water Supply," Water Resources Bull., Vol. 22, No. 6, pp. 927-940, Dec. 1986.

Lawler, J. P., F. E. Matusky, F. M. McGowan, and J. F. Larkin, "Modifying Operational and Structural Components of Existing Water Supply Systems to Increase Capacities," Annals of the New York Academy of Sciences, 1985.

Linsley,R.K., and J.B. Franzini, Water-Resources Engineering, 2nd. ed., McGraw-Hill, New York, 1972.

Loucks, D. P. and L. M. Falkson, "A Comparison of Some Dynamic, Linear, and Policy Iteration Methods for Reservoir Operation," Water Resources Bull., Vol. 6, No. 3., pp. 384-400, 1970.

Lucas, L. "OWASA Wants Durham Water Before Supplies Get Low," The Chapel Hill Herald, Vol. 1, No. 32, pp. 1-2, July 7, 1988.

Macy, P. and W. O. Maddaus, "Computer Analysis of Urban Conservation," Water Conservation News, March 1986.

Maidment, D. R. and E. Parzen, "Cascade Model of Monthly Municipal Water Use, WRR, Vol. 20, No. 1, pp. 15-23, Jan. 1984.

Mather, J.R. Water Resources Distribution, Use and Management, John Wiley and Sons, New York, 1984.

McCrodden, B. J. and R. E. Paddock, "Summary Report, Phase 1 - Safe Yield Review, Drought Management Plan for City of Durham, NC," Research Triangle Institute Report No. RTI/2297-00-01, Feb. 12, 1982.

McGarry, R.S., "Potomac River Basin Cooperation: A Success Story," Washington Suburban Sanitary Commission.

Meier, W. L., Jr. and C. S. Beighter, "An Optimization Method for Branching Multistage Water Resource Systems," Water Resources Res., Vol. 3, No. 3, pp. 645-654, 1967.

Moncur, J.E.T., "Urban Water Pricing and Drought Management," WRR, Vol. 23, No. 3, pp. 393-398, March 1987.

Moreau, D. H., "Risk Management for Water Supplies During Droughts," Paper presented at 15th Annual Wate Resources Conference, ASCE, Norfolk, VA, June 1-5, 1988.

_______, "Risk Management. . .," From Proceedings of 15th Annual Water Resources Conference, ASCE, Norfolk, VA, June 1-5, 1988.

_______, "An Operating Policy for a Public Surface Water Supply in Piedmont of North Carolina," draft report to WRRI, June 1987.

_______, "A Survey and Assessment of Public Water Supply Management During the Southeast Drought of 1986," project summary, June 1987.

_______, "Seasonal and Peak Daily Demands on Public Water Supplies in North Carolina," A Technical Note, Water Resources Research Institute of The University of North Carolina, Sept. 1984.

National Oceanic and Atmospheric Administration <u>Climatological Data North Carolina</u>, Vol. 91 Nos 5-10, 1986.

National Weather Service, "Drought in the Southeast is Probably the Worst in at Least 111 Years, "<u>Weekly Weather and Crop Bulletin</u>, Vol. 73, No. 11, Aug. 5, 1986.

New England River Basin Commission (NERBC), "Before the Well Runds Dry: A Handbook for Designing a Local Water Conservation Plan," Oct. 1980.

North Carolina Department of Natural Resources and Community Development, Office of Water Resources (NCDNRCD), "Preparing for Drought Conditions in North Carolina," 1982.

O'Neill, L., Director of Water and Sewer Utilities, City of High Point, personal communication, May 13, 1988.

Opricovic, S. and B. Djordjevic, "Optimal Long-Term Control of a Multipurpose Reservoir with Indirect Users," WRR, Vol. 12, No. 6, Dec. 1976.

Randall, D., M. H. Houck and J. R. Wright, "Simulating Water System Operation During Periods of Drought," <u>Journal of AWWA</u>, pp. 53-63, Aug. 1986.

Reinhold, R., "Nations Water Supplies are Bountiful but Supplies are Squandered," New York Times, Aug. 9, 1981.

Revelle, C. and J. Gundalach, "Linear Decision Rule in Reservoir Management and Design, 4, A Rule That Minimizes Output Variance," Water Resources Res., Vol. 11, No. 2, pp. 197-203, April 1975.

Revelle, C., E. Joeres and W. Kirby, "The Linear Decision Rule in Reservoir Management and Design, 1, Development of th Stochastic Model," Water Resources Res., Vol. 5, No. 4, pp. 767-777, Aug. 1969.

Revelle, C. and W. Kirby, "Linear Decision Rule in Reservoir Management and Design, 2, Performance Optimization," Water Resources Res., Vol. 6, No. 4, pp. 1033-1044.

Roefs, T.G. and L.D. Bodin, "Multireservoir Operation Studies," Water Resources Res., Vol. 6, No. 2, pp. 410-420, April 1970.

Rolan, A. T., Director, Dept. of Water Resources, City of Durham, personal communication, May 17, 1988.

Shaw, R., Assistant Director of Public Works, City of Greensboro, personal communication, May 17, 1988.

Shea, M. E., "Effectiveness of Drought Conservation Measures: Analysis and Applications," Master of Regional Planning Report, UNC-Chapel Hill, May 1988.

Simonovic, S.P. and M. A. Marino, "Reliability Programming in Reservoir Management, 2, Risk Loss Functions," WRR, Vol. 17, No. 4, pp. 822-826, Aug. 1981.

Strycharczyk, J. B. and J. R. Stedinger, "Evaluation of a 'Reliability Programming' Reservoir Model," Water Resources Res., Vol. 23, No. 2, pp. 225-229, Feb. 1987.

Takeuchi, K. and D. H. Moreau, "Optimal Control of Multiunit Interbasin Water Resources Res., Vol. 10, No. 3, pp. 407-414, June 1974.

Viessman, W., Jr., and C. Welty, Water Management Technology and Institutions, Harper and Row, New York, 1984.

Warwick, R. A., Drought Hazard in the United States: A Research Assessment, Institute of Behavioral Science, The University of Colorado, 1975.

White, G. F., "Dimensions of Drought Management for Public Water Supplies," From DMAIIOPWS, 1986.

Wilhite, D. A., "Drought Policy in the US and Australia: A Comparative Analysis," Water Resources Bull., AWRA, Vol. 22, No. 3, June 1986.

Yeh, W. W-G., "Reservoir Management and Operations Models: A State-of-the-Art Review," Water Resources Res., Vol. 21, No. 12, pp. 1797-1818, Dec. 1985.

Yeh, W. W-G. and L. Becker, "Multiobjective Analysis of Multireservoir Operations," WRR, Vol. 18, No. 5, pp. 1326-1336, Oct. 1982.

# APPENDIX

APPENDIX A1

SURVEY RESULTS

# PLEASE ASSIST OUR RESEARCH BY COMPLETING THIS SURVEY

The drought that occurred during the summer of 1986 had an adverse effect on a large number of communities in the Southeast. The purpose of this survey is to make a regionwide assessment of that drought, including an evaluation of how communities managed to balance demands and supplies during that period.

Your response to this very brief questionnaire will help us to identify which communities were affected. A follow-up survey of selected utilities will be used to get more detailed information.

Please circle the appropriate answer or fill in the blanks to the questions, put the questionnaire in the business reply envelope, and drop it in the mail.

Information about responses of individual communities will not be released without your permission.

Thank you for your assistance.

*Funding for this survey is provided in part by the U.S. Geological Survey as appropriated under Section 105 of the Water Resources Research Act of 1984. The balance is provided by the University of North Carolina.*

## QUESTIONS ABOUT THE IMPACT OF THE DROUGHT OF 1986

Did you request customers to reduce water use during 1986?

1. No
2. Yes

> Did you request customers to reduce their use voluntarily?
>
> 1. No
> 2. Yes
>
> Did you impose mandatory reductions in 1986 on customers through the use of ordinances, statutes, or other power of state or local governments?
>
> 1. No
> 2. Yes

Do you have an agreement with another utility to provide a supplementary supply of water during drought conditions?

1. No
2. Yes

> Did you purchase water under that agreement in 1986?
>
> 1. No
> 2. Yes
>
> Did you sell water to another utility in 1986?
>
> 1. No
> 2. Yes

Did you have an ordinance or other written policy for operating your water supply under drought conditions before the 1986 drought?

1. No
2. Yes

Was that policy invoked in 1986?

1. No
2. Yes

Have you developed a policy since 1986?

1. No
2. Yes

From whom did you get assistance in preparing your policy or ordinance? (Circle all that apply.)

1. Your own staff
2. Neighboring utilities or associations of utilities
3. Consultant
4. State government technical assistance program
5. A university-based technical assistance program
6. League of Municipalities or similar organization
7. Others

PLEASE CONTINUE →

Representative: Greg Allen
Name: Alabaster Water & Gas Board
Address1: P. O. Box 528
City: Alabaster
State: AL
Zip: 35007
Telephone: 205-663-6155
Pop: 14127
Title: Manager
Type: city
Comments:
Comments2:
highpop:

---

SURVEY RESULTS

Responded: 1

A.1 Did you request customers to reduce water use during 1986?
A.1: 1

A.1.a Did you request customers to reduce their use voluntarily?
A.1.a: 1

A.1.b Did you impose mandatory restrictions in 1986 on customers thro the use of ordinances, statutes, or other power of state or loca governments?
A.1.b: 0

A.2 Do you have an agreement with another utility to provide a supplementary supply of water during drought conditions?
A.2: 0

A.2.a Did you purchase water under that agreement in 1986?
A.2.a: -1

A.2.b Did you sell water to another utility in 1986?
A.2.b: -1

A.3 Did you have an ordinance or other written policy for operating your water supply under drought conditions before the 1986 drought?
A.3: 0

A.3.a Was that policy invoked in 1986?
A.3.a: -1

A.4 Have you developed a policy since 1986?
A.4: 0

A.5 From whom did you get assistance in preparing your policy or ordinan (circle all that apply)
A.5: 0

A.6 Do you have a report that describes the technical basis for the poli
A.6: -1

---

QUESTIONS ABOUT YOUR UTILITY

---

B.1 What was the average daily demand in MGD in 1986?
B.1: 3

B.2 Approximately how many customers did you serve in 1986?
B.2.a Residential?
B.2.a: 4800

B.2.b Other?
B.2.b: 1200

B.3 What was the safe yield of your water supply in MGD during 1986?
B.3: 3

B.4 How much was available from other sources (in MGD)?
B.4: 0

B.5 Has the capacity of your water supply been increased since 1986?
B.5: 0

B.6 Which of the following sources of water did you use in 1986?
(circle all that apply)
B.6: 2

B.6.a If you purchase water from another utility, are purchases made throughout the year, seasonally as requested, or strictly in an emergency?
B.6.a: 0

SOURCE OF WATER SUPPLY
1=surface 2=groundwater 3=purchase

Summary: @COUNT    Field: State    % Total

| | | B.5 = 1 | B.6 = '1 | B.6 = '12 | B.6 = '13 | B.6 = '123 | B.6 = '2 | B.6 = '23 | B.6 = '3 | ALL |
|---|---|---|---|---|---|---|---|---|---|---|
| S | AL | 3.55 | 2.84 | 1.18 | 0.71 | 0.00 | 2.13 | 0.71 | 1.66 | 9.95 |
| t | FL | 10.66 | 1.90 | 0.71 | 0.24 | 0.24 | 15.17 | 1.66 | 1.18 | 22.99 |
| a | GA | 5.92 | 3.55 | 0.24 | 0.71 | 0.47 | 4.03 | 0.24 | 1.42 | 11.61 |
| t | KY | 2.13 | 4.50 | 0.47 | 0.00 | 0.00 | 0.95 | 0.00 | 0.95 | 7.58 |
| e | MS | 0.95 | 0.00 | 0.47 | 0.00 | 0.00 | 3.55 | 0.00 | 0.00 | 4.50 |
| | NC | 2.37 | 8.77 | 0.47 | 0.71 | 0.00 | 1.66 | 0.71 | 0.47 | 13.27 |
| | SC | 3.32 | 3.55 | 0.95 | 0.24 | 0.24 | 1.42 | 0.00 | 1.42 | 9.24 |
| | TN | 2.61 | 4.50 | 1.18 | 0.95 | 0.71 | 2.84 | 0.24 | 0.71 | 12.56 |
| | VA | 0.71 | 3.32 | 1.42 | 0.24 | 0.71 | 0.00 | 0.71 | 1.66 | 8.29 |
| | ALL | 32.23 | 32.94 | 7.11 | 3.79 | 2.37 | 31.75 | 4.27 | 9.48 | 100.00 |

SOURCE OF WATER SUPPLY
1=surface 2=groundwater 3=purchase

Summary: @COUNT    Field: State    % Row

| | | B.5 = 1 | B.6 = '1 | B.6 = '12 | B.6 = '13 | B.6 = '123 | B.6 = '2 | B.6 = '23 | B.6 = '3 | ALL |
|---|---|---|---|---|---|---|---|---|---|---|
| S | AL | 35.71 | 28.57 | 11.90 | 7.14 | 0.00 | 21.43 | 7.14 | 16.67 | 100.00 |
| t | FL | 46.39 | 8.25 | 3.09 | 1.03 | 1.03 | 65.98 | 7.22 | 5.15 | 100.00 |
| a | GA | 51.02 | 30.61 | 2.04 | 6.12 | 4.08 | 34.69 | 2.04 | 12.24 | 100.00 |
| t | KY | 28.13 | 59.38 | 6.25 | 0.00 | 0.00 | 12.50 | 0.00 | 12.50 | 100.00 |
| e | MS | 21.05 | 0.00 | 10.53 | 0.00 | 0.00 | 78.95 | 0.00 | 0.00 | 100.00 |
| | NC | 17.86 | 66.07 | 3.57 | 5.36 | 0.00 | 12.50 | 5.36 | 3.57 | 100.00 |
| | SC | 35.90 | 38.46 | 10.26 | 2.56 | 2.56 | 15.38 | 0.00 | 15.38 | 100.00 |
| | TN | 20.75 | 35.85 | 9.43 | 7.55 | 5.66 | 22.64 | 1.89 | 5.66 | 100.00 |
| | VA | 8.57 | 40.00 | 17.14 | 2.86 | 8.57 | 0.00 | 8.57 | 20.00 | 100.00 |
| | ALL | 32.23 | 32.94 | 7.11 | 3.79 | 2.37 | 31.75 | 4.27 | 9.48 | 100.00 |

RESULTS OF DROUGHT SURVEY
ground water suppliers

Summary: @COUNT Field: State

| | | A.1 = 1 | A.1.a = | A.1.b = | A.2 = 1 | A.2.a = | A.2.b = | A.3 = 1 | A.3.a = | A.4 = 1 | A.6 = 1 | ALL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| S | AL | 10 | 10 | 1 | 7 | 3 | 6 | 5 | 2 | 3 | 2 | 17 |
| t | FL | 38 | 35 | 15 | 28 | 4 | 5 | 46 | 17 | 9 | 18 | 75 |
| a | GA | 10 | 9 | 5 | 6 | 4 | 1 | 14 | 5 | 8 | 8 | 21 |
| t | KY | 1 | 1 | 0 | 2 | 0 | 2 | 1 | 0 | 1 | 1 | 6 |
| e | MS | 1 | 1 | 0 | 1 | 0 | 0 | 2 | 0 | 1 | 0 | 17 |
| | NC | 6 | 5 | 2 | 5 | 1 | 2 | 5 | 2 | 1 | 0 | 12 |
| | SC | 5 | 4 | 1 | 5 | 1 | 2 | 2 | 0 | 7 | 3 | 11 |
| | TN | 5 | 5 | 0 | 10 | 4 | 8 | 1 | 0 | 0 | 0 | 21 |
| | VA | 6 | 5 | 2 | 5 | 2 | 4 | 8 | 4 | 1 | 2 | 12 |
| | ALL | 82 | 75 | 26 | 69 | 19 | 30 | 84 | 30 | 31 | 34 | 192 |
| | B.6 = '2' | 55 | 51 | 15 | 38 | 2 | 14 | 56 | 19 | 22 | 21 | 134 |
| | B.6 = '23' | 11 | 10 | 5 | 11 | 9 | 3 | 7 | 3 | 5 | 5 | 18 |
| | B.6 = '12' | 8 | 7 | 2 | 12 | 0 | 9 | 16 | 5 | 3 | 4 | 30 |
| | B.6 = '123 | 8 | 7 | 4 | 8 | 8 | 4 | 5 | 3 | 1 | 4 | 10 |

RESULTS OF DROUGHT SURVEY
ground water suppliers

Summary: @COUNT Field: State % Total

| | | A.1 = 1 | A.1.a = | A.1.b = | A.2 = 1 | A.2.a = | A.2.b = | A.3 = 1 | A.3.a = | A.4 = 1 | A.6 = 1 | ALL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| S | AL | 5.21 | 5.21 | 0.52 | 3.65 | 1.56 | 3.13 | 2.60 | 1.04 | 1.56 | 1.04 | 8.85 |
| t | FL | 19.79 | 18.23 | 7.81 | 14.58 | 2.08 | 2.60 | 23.96 | 8.85 | 4.69 | 9.38 | 39.06 |
| a | GA | 5.21 | 4.69 | 2.60 | 3.13 | 2.08 | 0.52 | 7.29 | 2.60 | 4.17 | 4.17 | 10.94 |
| t | KY | 0.52 | 0.52 | 0.00 | 1.04 | 0.00 | 1.04 | 0.52 | 0.00 | 0.52 | 0.52 | 3.13 |
| e | MS | 0.52 | 0.52 | 0.00 | 0.52 | 0.00 | 0.00 | 1.04 | 0.00 | 0.52 | 0.00 | 8.85 |
| | NC | 3.13 | 2.60 | 1.04 | 2.60 | 0.52 | 1.04 | 2.60 | 1.04 | 0.52 | 0.00 | 6.25 |
| | SC | 2.60 | 2.08 | 0.52 | 2.60 | 0.52 | 1.04 | 1.04 | 0.00 | 3.65 | 1.56 | 5.73 |
| | TN | 2.60 | 2.60 | 0.00 | 5.21 | 2.08 | 4.17 | 0.52 | 0.00 | 0.00 | 0.00 | 10.94 |
| | VA | 3.13 | 2.60 | 1.04 | 2.60 | 1.04 | 2.08 | 4.17 | 2.08 | 0.52 | 1.04 | 6.25 |
| | ALL | 42.71 | 39.06 | 13.54 | 35.94 | 9.90 | 15.63 | 43.75 | 15.63 | 16.15 | 17.71 | 100.00 |
| | B.6 = '2' | 28.65 | 26.56 | 7.81 | 19.79 | 1.04 | 7.29 | 29.17 | 9.90 | 11.46 | 10.94 | 69.79 |
| | B.6 = '23' | 5.73 | 5.21 | 2.60 | 5.73 | 4.69 | 1.56 | 3.65 | 1.56 | 2.60 | 2.60 | 9.38 |
| | B.6 = '12' | 4.17 | 3.65 | 1.04 | 6.25 | 0.00 | 4.69 | 8.33 | 2.60 | 1.56 | 2.08 | 15.63 |
| | B.6 = '123 | 4.17 | 3.65 | 2.08 | 4.17 | 4.17 | 2.08 | 2.60 | 1.56 | 0.52 | 2.08 | 5.21 |

RESULTS OF DROUGHT SURVEY
ground water suppliers

Summary: #COUNT Field: State % Row

| | | A.1 = 1 | A.1.a = | A.1.b = | A.2 = 1 | A.2.a = | A.2.b = | A.3 = 1 | A.3.a = | A.4 = 1 | A.6 = 1 | ALL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| S | AL | 58.82 | 58.82 | 5.88 | 41.18 | 17.65 | 35.29 | 29.41 | 11.76 | 17.65 | 11.76 | 100.00 |
| t | FL | 50.67 | 46.67 | 20.00 | 37.33 | 5.33 | 6.67 | 61.33 | 22.67 | 12.00 | 24.00 | 100.00 |
| a | GA | 47.62 | 42.86 | 23.81 | 28.57 | 19.05 | 4.76 | 66.67 | 23.81 | 38.10 | 38.10 | 100.00 |
| t | KY | 16.67 | 16.67 | 0.00 | 33.33 | 0.00 | 33.33 | 16.67 | 0.00 | 16.67 | 16.67 | 100.00 |
| e | MS | 5.88 | 5.88 | 0.00 | 5.88 | 0.00 | 0.00 | 11.76 | 0.00 | 5.88 | 0.00 | 100.00 |
| | NC | 50.00 | 41.67 | 16.67 | 41.67 | 8.33 | 16.67 | 41.67 | 16.67 | 8.33 | 0.00 | 100.00 |
| | SC | 45.45 | 36.36 | 9.09 | 45.45 | 9.09 | 18.18 | 18.18 | 0.00 | 63.64 | 27.27 | 100.00 |
| | TN | 23.81 | 23.81 | 0.00 | 47.62 | 19.05 | 38.10 | 4.76 | 0.00 | 0.00 | 0.00 | 100.00 |
| | VA | 50.00 | 41.67 | 16.67 | 41.67 | 16.67 | 33.33 | 66.67 | 33.33 | 8.33 | 16.67 | 100.00 |
| | ALL | 42.71 | 39.06 | 13.54 | 35.94 | 9.90 | 15.63 | 43.75 | 15.63 | 16.15 | 17.71 | 100.00 |
| | B.6 = '2' | 41.04 | 38.06 | 11.19 | 28.36 | 1.49 | 10.45 | 41.79 | 14.18 | 16.42 | 15.67 | 100.00 |
| | B.6 = '23' | 61.11 | 55.56 | 27.78 | 61.11 | 50.00 | 16.67 | 38.89 | 16.67 | 27.78 | 27.78 | 100.00 |
| | B.6 = '12' | 26.67 | 23.33 | 6.67 | 40.00 | 0.00 | 30.00 | 53.33 | 16.67 | 10.00 | 13.33 | 100.00 |
| | B.6 = '123 | 80.00 | 70.00 | 40.00 | 80.00 | 80.00 | 40.00 | 50.00 | 30.00 | 10.00 | 40.00 | 100.00 |

RESULTS OF DROUGHT SURVEY
surface water supplys

Summary: #COUNT Field: State

| | | A.1 = 1 | A.1.a = | A.1.b = | A.2 = 1 | A.2.a = | A.2.b = | A.3 = 1 | A.3.a = | A.4 = 1 | A.6 = 1 | ALL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| S | AL | 2 | 2 | 2 | 6 | 1 | 5 | 4 | 1 | 3 | 0 | 20 |
| t | FL | 7 | 7 | 4 | 9 | 2 | 3 | 12 | 5 | 1 | 7 | 13 |
| a | GA | 19 | 16 | 14 | 11 | 5 | 8 | 16 | 13 | 6 | 12 | 21 |
| t | KY | 4 | 4 | 1 | 4 | 0 | 4 | 8 | 1 | 0 | 3 | 21 |
| e | MS | 0 | 0 | 0 | 1 | 0 | 0 | 2 | 0 | 0 | 0 | 2 |
| | NC | 16 | 16 | 4 | 10 | 2 | 8 | 13 | 7 | 8 | 6 | 42 |
| | SC | 14 | 12 | 3 | 8 | 2 | 4 | 6 | 1 | 13 | 7 | 21 |
| | TN | 10 | 10 | 1 | 14 | 5 | 15 | 7 | 1 | 3 | 2 | 31 |
| | VA | 6 | 5 | 2 | 9 | 2 | 9 | 11 | 5 | 2 | 2 | 24 |
| | ALL | 78 | 72 | 31 | 72 | 19 | 56 | 79 | 34 | 36 | 39 | 195 |
| | B.6 = '1' | 52 | 49 | 18 | 40 | 0 | 35 | 49 | 21 | 28 | 28 | 139 |
| | B.6 = '13' | 10 | 9 | 7 | 12 | 11 | 8 | 9 | 5 | 4 | 3 | 16 |
| | B.6 = '12' | 3 | 7 | 2 | 12 | 0 | 9 | 16 | 5 | 3 | 4 | 30 |
| | B.6 = '123 | 8 | 7 | 4 | 8 | 0 | 4 | 5 | 3 | 1 | 4 | 10 |

RESULTS OF DROUGHT SURVEY
surface water supplys

Summary: @COUNT Field: State % Total

| | | A.1 = 1 | A.1.a = | A.1.b = | A.2 = 1 | A.2.a = | A.2.b = | A.3 = 1 | A.3.a = | A.4 = 1 | A.6 = 1 | ALL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| S | AL | 1.03 | 1.03 | 1.03 | 3.08 | 0.51 | 2.56 | 2.05 | 0.51 | 1.54 | 0.00 | 10.26 |
| t | FL | 3.59 | 3.59 | 2.05 | 4.62 | 1.03 | 1.54 | 6.15 | 2.56 | 0.51 | 3.59 | 6.67 |
| a | GA | 9.74 | 8.21 | 7.18 | 5.64 | 2.56 | 4.10 | 8.21 | 6.67 | 3.08 | 6.15 | 10.77 |
| t | KY | 2.05 | 2.05 | 0.51 | 2.05 | 0.00 | 2.05 | 4.10 | 0.51 | 0.00 | 1.54 | 10.77 |
| e | MS | 0.00 | 0.00 | 0.00 | 0.51 | 0.00 | 0.00 | 1.03 | 0.00 | 0.00 | 0.00 | 1.03 |
| | NC | 8.21 | 6.21 | 2.05 | 5.13 | 1.03 | 4.10 | 6.67 | 3.59 | 4.10 | 3.08 | 21.54 |
| | SC | 7.18 | 6.15 | 1.54 | 4.10 | 1.03 | 2.05 | 3.08 | 0.51 | 6.67 | 3.59 | 10.77 |
| | TN | 5.13 | 5.13 | 0.51 | 7.18 | 2.56 | 7.69 | 3.59 | 0.51 | 1.54 | 1.03 | 15.90 |
| | VA | 3.08 | 2.56 | 1.03 | 4.62 | 1.03 | 4.62 | 5.64 | 2.56 | 1.03 | 1.03 | 12.31 |
| | ALL | 40.00 | 36.92 | 15.90 | 36.92 | 9.74 | 28.72 | 40.51 | 17.44 | 18.46 | 20.00 | 100.00 |
| | B.6 = '1' | 26.67 | 25.13 | 9.23 | 20.51 | 0.00 | 17.95 | 25.13 | 10.77 | 14.36 | 14.36 | 71.28 |
| | B.6 = '13' | 5.13 | 4.62 | 3.59 | 6.15 | 5.64 | 4.10 | 4.62 | 2.56 | 2.05 | 1.54 | 8.21 |
| | B.6 = '12' | 4.10 | 3.59 | 1.03 | 6.15 | 0.00 | 4.62 | 8.21 | 2.56 | 1.54 | 2.05 | 15.38 |
| | B.6 = '123 | 4.10 | 3.59 | 2.05 | 4.10 | 4.10 | 2.05 | 2.56 | 1.54 | 0.51 | 2.05 | 5.13 |

RESULTS OF DROUGHT SURVEY
surface water supplys

Summary: @COUNT Field: State % Row

| | | A.1 = 1 | A.1.a = | A.1.b = | A.2 = 1 | A.2.a = | A.2.b = | A.3 = 1 | A.3.a = | A.4 = 1 | A.6 = 1 | ALL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| S | AL | 10.00 | 10.00 | 10.00 | 30.00 | 5.00 | 25.00 | 20.00 | 5.00 | 15.00 | 0.00 | 100.00 |
| t | FL | 53.85 | 53.85 | 30.77 | 69.23 | 15.38 | 23.08 | 92.31 | 38.46 | 7.69 | 53.85 | 100.00 |
| a | GA | 90.48 | 76.19 | 66.67 | 52.38 | 23.81 | 38.10 | 76.19 | 61.90 | 28.57 | 57.14 | 100.00 |
| t | KY | 19.05 | 19.05 | 4.76 | 19.05 | 0.00 | 19.05 | 38.10 | 4.76 | 0.00 | 14.29 | 100.00 |
| e | MS | 0.00 | 0.00 | 0.00 | 50.00 | 0.00 | 0.00 | 100.00 | 0.00 | 0.00 | 0.00 | 100.00 |
| | NC | 38.10 | 38.10 | 9.52 | 23.81 | 4.76 | 19.05 | 30.95 | 16.67 | 19.05 | 14.29 | 100.00 |
| | SC | 66.67 | 57.14 | 14.29 | 38.10 | 9.52 | 19.05 | 28.57 | 4.76 | 61.90 | 33.33 | 100.00 |
| | TN | 32.26 | 32.26 | 3.23 | 45.16 | 16.13 | 48.39 | 22.58 | 3.23 | 9.68 | 6.45 | 100.00 |
| | VA | 25.00 | 20.83 | 8.33 | 37.50 | 8.33 | 37.50 | 45.83 | 20.83 | 8.33 | 8.33 | 100.00 |
| | ALL | 40.00 | 36.92 | 15.90 | 36.92 | 9.74 | 28.72 | 40.51 | 17.44 | 18.46 | 20.00 | 100.00 |
| | B.6 = '1' | 37.41 | 35.25 | 12.95 | 28.78 | 0.00 | 25.18 | 35.25 | 15.11 | 20.14 | 20.14 | 100.00 |
| | B.6 = '13' | 62.50 | 56.25 | 43.75 | 75.00 | 68.75 | 50.00 | 56.25 | 31.25 | 25.00 | 18.75 | 100.00 |
| | B.6 = '12' | 26.67 | 23.33 | 6.67 | 40.00 | 0.00 | 30.00 | 53.33 | 16.67 | 10.00 | 13.33 | 100.00 |
| | B.6 = '123 | 80.00 | 70.00 | 40.00 | 80.00 | 80.00 | 40.00 | 50.00 | 30.00 | 10.00 | 40.00 | 100.00 |

UTILITIES WHO PURCHASE WATER

1=all year  2=seasonally  3=emergency only

Summary: @COUNT    Field: State

| | | B.6 = '..3 | B.6.a = '1 | B.6.a = '..2 | B.6.a = '..3 | ALL |
|---|---|---|---|---|---|---|
| S | AL | 13 | 10 | 4 | 1 | 42 |
| t | FL | 14 | 14 | 0 | 29 | 97 |
| a | GA | 12 | 11 | 1 | 7 | 49 |
| t | KY | 4 | 4 | 1 | 1 | 32 |
| e | MS | 0 | 0 | 0 | 2 | 19 |
| | NC | 8 | 5 | 0 | 7 | 56 |
| | SC | 8 | 6 | 2 | 7 | 39 |
| | TN | 11 | 9 | 1 | 5 | 53 |
| | VA | 14 | 14 | 1 | 5 | 35 |
| | ALL | 84 | 73 | 10 | 64 | 422 |
| | B.6 = '..3 | 84 | 71 | 9 | 12 | 84 |

UTILITIES WHO PURCHASE WATER

1=all year  2=seasonally  3=emergency only

Summary: @COUNT    Field: State    % Total

| | | B.6 = '..3 | B.6.a = '1 | B.6.a = '..2 | B.6.a = '..3 | ALL |
|---|---|---|---|---|---|---|
| S | AL | 3.08 | 2.37 | 0.95 | 0.24 | 9.95 |
| t | FL | 3.32 | 3.32 | 0.00 | 6.87 | 22.99 |
| a | GA | 2.84 | 2.61 | 0.24 | 1.66 | 11.61 |
| t | KY | 0.95 | 0.95 | 0.24 | 0.24 | 7.58 |
| e | MS | 0.00 | 0.00 | 0.00 | 0.47 | 4.50 |
| | NC | 1.90 | 1.18 | 0.00 | 1.66 | 13.27 |
| | SC | 1.90 | 1.42 | 0.47 | 1.66 | 9.24 |
| | TN | 2.61 | 2.13 | 0.24 | 1.18 | 12.56 |
| | VA | 3.32 | 3.32 | 0.24 | 1.18 | 8.29 |
| | ALL | 19.91 | 17.30 | 2.37 | 15.17 | 100.00 |
| | B.6 = '..3 | 19.91 | 16.82 | 2.13 | 2.84 | 19.91 |

ALABAMA - RESULTS OF DROUGHT SURVEY
total yes responses

Summary: @COUNT Field: State

| | A.1 = 1 | A.1.a = | A.1.b = | A.2 = 1 | A.2.a = | A.2.b = | A.3 = 1 | A.3.a = | A.4 = 1 | A.6 = 1 | ALL |
|---|---|---|---|---|---|---|---|---|---|---|---|
| AL | 15 | 15 | 2 | 16 | 5 | 13 | 9 | 2 | 6 | 2 | 42 |
| A.1.a = 1 | 15 | 15 | 2 | 7 | 4 | 6 | 3 | 2 | 3 | 2 | 15 |
| A.1.b = 1 | 2 | 2 | 2 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 2 |
| B.5 = 1 | 7 | 7 | 1 | 5 | 2 | 4 | 1 | 0 | 4 | 0 | 15 |
| B.6 = '1.. | 2 | 2 | 2 | 6 | 1 | 5 | 4 | 1 | 3 | 0 | 20 |
| B.6 = '..2 | 10 | 10 | 1 | 7 | 3 | 6 | 5 | 2 | 3 | 2 | 17 |
| B.6 = '..3 | 6 | 6 | 1 | 6 | 5 | 5 | 3 | 0 | 3 | 1 | 13 |

ALABAMA - RESULTS OF DROUGHT SURVEY
% of row of positive responses

Summary: @COUNT Field: State % Row

| | | A.1 = 1 | A.1.a = | A.1.b = | A.2 = 1 | A.2.a = | A.2.b = | A.3 = 1 | A.3.a = | A.4 = 1 | A.6 = 1 | ALL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| S | AL | 35.71 | 35.71 | 4.76 | 38.10 | 11.90 | 30.95 | 21.43 | 4.76 | 14.29 | 4.76 | 100.00 |
| t | A.1.a = 1 | 100.00 | 100.00 | 13.33 | 46.67 | 26.67 | 40.00 | 20.00 | 13.33 | 20.00 | 13.33 | 100.00 |
| a | A.1.b = 1 | 100.00 | 100.00 | 100.00 | 50.00 | 50.00 | 0.00 | 50.00 | 50.00 | 50.00 | 0.00 | 100.00 |
| t | B.5 = 1 | 46.67 | 46.67 | 6.67 | 33.33 | 13.33 | 26.67 | 6.67 | 0.00 | 26.67 | 0.00 | 100.00 |
| e | B.6 = '1.. | 10.00 | 10.00 | 10.00 | 30.00 | 5.00 | 25.00 | 20.00 | 5.00 | 15.00 | 0.00 | 100.00 |
| | B.6 = '..2 | 58.82 | 58.82 | 5.88 | 41.18 | 17.65 | 35.29 | 29.41 | 11.76 | 17.65 | 11.76 | 100.00 |
| | B.6 = '..3 | 46.15 | 46.15 | 7.69 | 46.15 | 38.46 | 38.46 | 23.08 | 0.00 | 23.08 | 7.69 | 100.00 |

ALABAMA - RESULTS OF DROUGHT SURVEY
% of column of positive responses

Summary: @COUNT Field: State % Column

| | | A.1 = 1 | A.1.a = | A.1.b = | A.2 = 1 | A.2.a = | A.2.b = | A.3 = 1 | A.3.a = | A.4 = 1 | A.6 = 1 | ALL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| S | AL | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 |
| t | A.1.a = 1 | 100.00 | 100.00 | 100.00 | 43.75 | 80.00 | 46.15 | 33.33 | 100.00 | 50.00 | 100.00 | 35.71 |
| a | A.1.b = 1 | 13.33 | 13.33 | 100.00 | 6.25 | 20.00 | 0.00 | 11.11 | 50.00 | 16.67 | 0.00 | 4.76 |
| t | B.5 = 1 | 46.67 | 46.67 | 50.00 | 31.25 | 40.00 | 30.77 | 11.11 | 0.00 | 66.67 | 0.00 | 35.71 |
| e | B.6 = '1.. | 13.33 | 13.33 | 100.00 | 37.50 | 20.00 | 38.46 | 44.44 | 50.00 | 50.00 | 0.00 | 47.62 |
| | B.6 = '..2 | 66.67 | 66.67 | 50.00 | 43.75 | 60.00 | 46.15 | 55.56 | 100.00 | 50.00 | 100.00 | 40.48 |
| | B.6 = '..3 | 40.00 | 40.00 | 50.00 | 37.50 | 100.00 | 38.46 | 33.33 | 0.00 | 50.00 | 50.00 | 30.95 |

FLORIDA - RESULTS OF DROUGHT SURVEY
toal yes responses

Summary: @COUNT Field: State

| | | A.1 = 1 | A.1.a = | A.1.b = | A.2 = 1 | A.2.a = | A.2.b = | A.3 = 1 | A.3.a = | A.4 = 1 | A.6 = 1 | ALL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| S | FL | 45 | 42 | 19 | 36 | 5 | 7 | 59 | 22 | 10 | 24 | 97 |
| t | A.1.a = 1 | 42 | 42 | 16 | 18 | 4 | 5 | 30 | 19 | 5 | 14 | 42 |
| a | A.1.b = 1 | 19 | 16 | 19 | 8 | 4 | 3 | 16 | 14 | 4 | 8 | 19 |
| t | B.5 = 1 | 29 | 28 | 11 | 18 | 3 | 7 | 29 | 14 | 3 | 15 | 45 |
| e | B.6 = '1.. | 7 | 7 | 4 | 9 | 2 | 3 | 12 | 5 | 1 | 7 | 13 |
| | B.6 = '..2 | 38 | 35 | 15 | 28 | 4 | 5 | 46 | 17 | 9 | 18 | 75 |
| | B.6 = '..3 | 6 | 5 | 5 | 7 | 5 | 1 | 9 | 3 | 2 | 6 | 14 |

FLORIDA - RESULTS OF DROUGHT SURVEY
% by row of positive responses

Summary: @COUNT Field: State % Row

| | | A.1 = 1 | A.1.a = | A.1.b = | A.2 = 1 | A.2.a = | A.2.b = | A.3 = 1 | A.3.a = | A.4 = 1 | A.6 = 1 | ALL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| S | FL | 46.39 | 43.30 | 19.59 | 37.11 | 5.15 | 7.22 | 60.82 | 22.68 | 10.31 | 24.74 | 100.00 |
| t | A.1.a = 1 | 100.00 | 100.00 | 38.10 | 42.86 | 9.52 | 11.90 | 71.43 | 45.24 | 11.90 | 33.33 | 100.00 |
| a | A.1.b = 1 | 100.00 | 84.21 | 100.00 | 42.11 | 21.05 | 15.79 | 84.21 | 73.68 | 21.05 | 42.11 | 100.00 |
| t | B.5 = 1 | 64.44 | 62.22 | 24.44 | 40.00 | 6.67 | 15.56 | 64.44 | 31.11 | 6.67 | 33.33 | 100.00 |
| e | B.6 = '1.. | 53.85 | 53.85 | 30.77 | 69.23 | 15.38 | 23.08 | 92.31 | 38.46 | 7.69 | 53.85 | 100.00 |
| | B.6 = '..2 | 50.67 | 46.67 | 20.00 | 37.33 | 5.33 | 6.67 | 61.33 | 22.67 | 12.00 | 24.00 | 100.00 |
| | B.6 = '..3 | 42.86 | 35.71 | 35.71 | 50.00 | 35.71 | 7.14 | 64.29 | 21.43 | 14.29 | 42.86 | 100.00 |

FLORIDA - RESULTS OF DROUGHT SURVEY
% by column of positive responses

Summary: @COUNT Field: State % Column

| | | A.1 = 1 | A.1.a = | A.1.b = | A.2 = 1 | A.2.a = | A.2.b = | A.3 = 1 | A.3.a = | A.4 = 1 | A.6 = 1 | ALL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| S | FL | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 |
| t | A.1.a = 1 | 93.33 | 100.00 | 84.21 | 50.00 | 80.00 | 71.43 | 50.85 | 86.36 | 50.00 | 58.33 | 43.30 |
| a | A.1.b = 1 | 42.22 | 38.10 | 100.00 | 22.22 | 80.00 | 42.86 | 27.12 | 63.64 | 40.00 | 33.33 | 19.59 |
| t | B.5 = 1 | 64.44 | 66.67 | 57.89 | 50.00 | 60.00 | 100.00 | 49.15 | 63.64 | 30.00 | 62.50 | 46.39 |
| e | B.6 = '1.. | 15.56 | 16.67 | 21.05 | 25.00 | 40.00 | 42.86 | 20.34 | 22.73 | 10.00 | 29.17 | 13.40 |
| | B.6 = '..2 | 84.44 | 83.33 | 78.95 | 77.78 | 80.00 | 71.43 | 77.97 | 77.27 | 90.00 | 75.00 | 77.32 |
| | B.6 = '..3 | 13.33 | 11.90 | 26.32 | 19.44 | 100.00 | 14.29 | 15.25 | 13.64 | 20.00 | 25.00 | 14.43 |

## GEORGIA - RESULTS OF DROUGHT SURVEY
## TOTAL YES RESPONSES

Summary: @COUNT          Field: State

| | | A.1 = 1 | A.1.a = | A.1.b = | A.2 = 1 | A.2.a = | A.2.b = | A.3 = 1 | A.3.a = | A.4 = 1 | A.6 = 1 | ALL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| S | GA | 35 | 30 | 24 | 16 | 9 | 11 | 32 | 20 | 18 | 22 | 49 |
| t | A.1.a = 1 | 30 | 30 | 19 | 12 | 6 | 9 | 20 | 17 | 12 | 16 | 30 |
| a | A.1.b = 1 | 24 | 19 | 24 | 9 | 6 | 7 | 15 | 14 | 9 | 11 | 24 |
| t | B.5 = 1 | 18 | 16 | 14 | 10 | 6 | 7 | 17 | 11 | 9 | 12 | 25 |
| e | B.6 = '1.. | 19 | 16 | 14 | 11 | 5 | 8 | 16 | 13 | 6 | 12 | 21 |
| | B.6 = '..2 | 10 | 9 | 5 | 6 | 4 | 1 | 14 | 5 | 8 | 8 | 21 |
| | B.6 = '..3 | 11 | 9 | 10 | 7 | 7 | 3 | 8 | 7 | 6 | 6 | 12 |

## GEORGIA - RESULTS OF DROUGHT SURVEY
## % BY ROW OF POSITIVE RESPONSES

Summary: @COUNT          Field: State          % Row

| | | A.1 = 1 | A.1.a = | A.1.b = | A.2 = 1 | A.2.a = | A.2.b = | A.3 = 1 | A.3.a = | A.4 = 1 | A.6 = 1 | ALL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| S | GA | 71.43 | 61.22 | 48.98 | 32.65 | 18.37 | 22.45 | 65.31 | 40.82 | 36.73 | 44.90 | 100.00 |
| t | A.1.a = 1 | 100.00 | 100.00 | 63.33 | 40.00 | 20.00 | 30.00 | 66.67 | 56.67 | 40.00 | 53.33 | 100.00 |
| a | A.1.b = 1 | 100.00 | 79.17 | 100.00 | 37.50 | 25.00 | 29.17 | 62.50 | 58.33 | 37.50 | 45.83 | 100.00 |
| t | B.5 = 1 | 72.00 | 64.00 | 56.00 | 40.00 | 24.00 | 28.00 | 68.00 | 44.00 | 36.00 | 48.00 | 100.00 |
| e | B.6 = '1.. | 90.48 | 76.19 | 66.67 | 52.38 | 23.81 | 38.10 | 76.19 | 61.90 | 28.57 | 57.14 | 100.00 |
| | B.6 = '..2 | 47.62 | 42.86 | 23.81 | 28.57 | 19.05 | 4.76 | 66.67 | 23.81 | 38.10 | 38.10 | 100.00 |
| | B.6 = '..3 | 91.67 | 75.00 | 83.33 | 58.33 | 58.33 | 25.00 | 66.67 | 58.33 | 50.00 | 50.00 | 100.00 |

## GEORGIA - RESULTS OF DROUGHT SURVEY
## % BY COLUMN OF POSITIVE RESPONSES

Summary: @COUNT          Field: State          % Column

| | | A.1 = 1 | A.1.a = | A.1.b = | A.2 = 1 | A.2.a = | A.2.b = | A.3 = 1 | A.3.a = | A.4 = 1 | A.6 = 1 | ALL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| S | GA | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 |
| t | A.1.a = 1 | 85.71 | 100.00 | 79.17 | 75.00 | 66.67 | 81.82 | 62.50 | 85.00 | 66.67 | 72.73 | 61.22 |
| a | A.1.b = 1 | 68.57 | 63.33 | 100.00 | 56.25 | 66.67 | 63.64 | 46.88 | 70.00 | 50.00 | 50.00 | 48.98 |
| t | B.5 = 1 | 51.43 | 53.33 | 58.33 | 62.50 | 66.67 | 63.64 | 53.13 | 55.00 | 50.00 | 54.55 | 51.02 |
| e | B.6 = '1.. | 54.29 | 53.33 | 58.33 | 68.75 | 55.56 | 72.73 | 50.00 | 65.00 | 33.33 | 54.55 | 42.86 |
| | B.6 = '..2 | 28.57 | 30.00 | 20.83 | 37.50 | 44.44 | 9.09 | 43.75 | 25.00 | 44.44 | 36.36 | 42.86 |
| | B.6 = '..3 | 31.43 | 30.00 | 41.67 | 43.75 | 77.78 | 27.27 | 25.00 | 35.00 | 33.33 | 27.27 | 24.49 |

KENTUCKY - RESULTS OF DROUGHT SURVEY
total yes responses

Summary: @COUNT Field: State

| | | A.1 = 1 | A.1.a = | A.1.b = | A.2 = 1 | A.2.a = | A.2.b = | A.3 = 1 | A.3.a = | A.4 = 1 | A.6 = 1 | ALL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| S | KY | 6 | 6 | 1 | 7 | 2 | 6 | 8 | 1 | 2 | 4 | 32 |
| t | A.1.a = 1 | 6 | 6 | 1 | 2 | 1 | 1 | 3 | 1 | 1 | 1 | 6 |
| a | A.1.b = 1 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 1 |
| t | B.5 = 1 | 3 | 3 | 1 | 4 | 1 | 3 | 2 | 1 | 2 | 2 | 9 |
| e | B.6 = '1.. | 4 | 4 | 1 | 4 | 0 | 4 | 8 | 1 | 0 | 3 | 21 |
| | B.6 = '..2 | 1 | 1 | 0 | 2 | 0 | 2 | 1 | 0 | 1 | 1 | 6 |
| | B.6 = '..3 | 2 | 2 | 0 | 2 | 2 | 1 | 0 | 0 | 1 | 0 | 4 |

KENTUCKY - RESULTS OF DROUGHT SURVEY
% BY ROW OF POSITIVE RESPONSES

Summary: @COUNT Field: State % Row

| | | A.1 = 1 | A.1.a = | A.1.b = | A.2 = 1 | A.2.a = | A.2.b = | A.3 = 1 | A.3.a = | A.4 = 1 | A.6 = 1 | ALL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| S | KY | 18.75 | 18.75 | 3.13 | 21.88 | 6.25 | 18.75 | 25.00 | 3.13 | 6.25 | 12.50 | 100.00 |
| t | A.1.a = 1 | 100.00 | 100.00 | 16.67 | 33.33 | 16.67 | 16.67 | 50.00 | 16.67 | 16.67 | 16.67 | 100.00 |
| a | A.1.b = 1 | 100.00 | 100.00 | 100.00 | 0.00 | 0.00 | 0.00 | 100.00 | 100.00 | 0.00 | 0.00 | 100.00 |
| t | B.5 = 1 | 33.33 | 33.33 | 11.11 | 44.44 | 11.11 | 33.33 | 22.22 | 11.11 | 22.22 | 22.22 | 100.00 |
| e | B.6 = '1.. | 19.05 | 19.05 | 4.76 | 19.05 | 0.00 | 19.05 | 38.10 | 4.76 | 0.00 | 14.29 | 100.00 |
| | B.6 = '..2 | 16.67 | 16.67 | 0.00 | 33.33 | 0.00 | 33.33 | 16.67 | 0.00 | 16.67 | 16.67 | 100.00 |
| | B.6 = '..3 | 50.00 | 50.00 | 0.00 | 50.00 | 50.00 | 25.00 | 0.00 | 0.00 | 25.00 | 0.00 | 100.00 |

KENTUCKY - RESULTS OF DROUGHT SURVEY
% BY COLUMN OF POSITIVE RESPONSES

Summary: @COUNT Field: State % Column

| | | A.1 = 1 | A.1.a = | A.1.b = | A.2 = 1 | A.2.a = | A.2.b = | A.3 = 1 | A.3.a = | A.4 = 1 | A.6 = 1 | ALL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| S | KY | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 |
| t | A.1.a = 1 | 100.00 | 100.00 | 100.00 | 28.57 | 50.00 | 16.67 | 37.50 | 100.00 | 50.00 | 25.00 | 18.75 |
| a | A.1.b = 1 | 16.67 | 16.67 | 100.00 | 0.00 | 0.00 | 0.00 | 12.50 | 100.00 | 0.00 | 0.00 | 3.13 |
| t | B.5 = 1 | 50.00 | 50.00 | 100.00 | 57.14 | 50.00 | 50.00 | 25.00 | 100.00 | 100.00 | 50.00 | 28.13 |
| e | B.6 = '1.. | 66.67 | 66.67 | 100.00 | 57.14 | 0.00 | 66.67 | 100.00 | 100.00 | 0.00 | 75.00 | 65.63 |
| | B.6 = '..2 | 16.67 | 16.67 | 0.00 | 28.57 | 0.00 | 33.33 | 12.50 | 0.00 | 50.00 | 25.00 | 18.75 |
| | B.6 = '..3 | 33.33 | 33.33 | 0.00 | 28.57 | 100.00 | 16.67 | 0.00 | 0.00 | 50.00 | 0.00 | 12.50 |

## MISSISSIPPI - RESULTS OF DROUGHT SURVEY
### TOTAL YES RESPONSES

Summary: @COUNT      Field: State

| | | A.1 = 1 | A.1.a = | A.1.b = | A.2 = 1 | A.2.a = | A.2.b = | A.3 = 1 | A.3.a = | A.4 = 1 | A.6 = 1 | ALL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| S | MS | 1 | 1 | 0 | 1 | 0 | 0 | 2 | 0 | 1 | 0 | 19 |
| t | A.1.a = 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| a | A.1.b = 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| t | B.5 = 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 |
| e | B.6 = '1.. | 0 | 0 | 0 | 1 | 0 | 0 | 2 | 0 | 0 | 0 | 2 |
| | B.6 = '..2 | 1 | 1 | 0 | 1 | 0 | 0 | 2 | 0 | 1 | 0 | 17 |
| | B.6 = '..3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

## MISSISSIPPI - RESULTS OF DROUGHT SURVEY
### % BY ROW OF POSITIVE RESPONSES

Summary: @COUNT      Field: State      % Row

| | | A.1 = 1 | A.1.a = | A.1.b = | A.2 = 1 | A.2.a = | A.2.b = | A.3 = 1 | A.3.a = | A.4 = 1 | A.6 = 1 | ALL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| S | MS | 5.26 | 5.26 | 0.00 | 5.26 | 0.00 | 0.00 | 10.53 | 0.00 | 5.26 | 0.00 | 100.00 |
| t | A.1.a = 1 | 100.00 | 100.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 100.00 |
| a | A.1.b = 1 | | | | | | | | | | | |
| t | B.5 = 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 100.00 |
| e | B.6 = '1.. | 0.00 | 0.00 | 0.00 | 50.00 | 0.00 | 0.00 | 100.00 | 0.00 | 0.00 | 0.00 | 100.00 |
| | B.6 = '..2 | 5.88 | 5.88 | 0.00 | 5.88 | 0.00 | 0.00 | 11.76 | 0.00 | 5.88 | 0.00 | 100.00 |
| | B.6 = '..3 | | | | | | | | | | | |

## MISSISSIPPI - RESULTS OF DROUGHT SURVEY
### % BY COLUMN OF POSITIVE RESPONSES

Summary: @COUNT      Field: State      % Column

| | | A.1 = 1 | A.1.a = | A.1.b = | A.2 = 1 | A.2.a = | A.2.b = | A.3 = 1 | A.3.a = | A.4 = 1 | A.6 = 1 | ALL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| S | MS | 100.00 | 100.00 | | 100.00 | | | 100.00 | | 100.00 | | 100.00 |
| t | A.1.a = 1 | 100.00 | 100.00 | | 0.00 | | | 0.00 | | 0.00 | | 5.26 |
| a | A.1.b = 1 | 0.00 | 0.00 | | 0.00 | | | 0.00 | | 0.00 | | 0.00 |
| t | B.5 = 1 | 0.00 | 0.00 | | 0.00 | | | 0.00 | | 0.00 | | 21.05 |
| e | B.6 = '1.. | 0.00 | 0.00 | | 100.00 | | | 100.00 | | 0.00 | | 10.53 |
| | B.6 = '..2 | 100.00 | 100.00 | | 100.00 | | | 100.00 | | 100.00 | | 89.47 |
| | B.6 = '..3 | 0.00 | 0.00 | | 0.00 | | | 0.00 | | 0.00 | | 0.00 |

1. Continuing Voluntary Conservation Practices.

Customers shall be encouraged to observe water conservation measures to reduce the wasting of water as follows:

[illegible] plumbing and fixtures for leaks annually, [illegible] necessary repairs.

[illegible] leaking faucets whenever they develop.

[illegible] drinking water in the refrigerator [illegible] running [illegible] cool at the tap.

[illegible] shower for bathing purposes or reduce the [illegible] of water used for tub baths. Limit [illegible] to four (4) minutes where possible.

[illegible] free running faucets while [illegible] [illegible] teeth or [illegible].

(f) [illegible] water flow restriction devices to shower heads.

(g) Install water-saving devices such as plastic bottles or commercial units in toilet tanks.

(h) Wash full loads in clothes washers and dishwashers.

[illegible] [illegible] when and where feasible [illegible] shall [illegible] [illegible], particularly commercial and [illegible] [illegible].

[illegible] II: Voluntary Conservation.

Customers [illegible] be encouraged to observe the [illegible] of Stage I and to increase the [illegible] of the conservation effort as follows:

(a) Limit the use of clothes washers and dishwashers [illegible] when [illegible] fully loaded.

[illegible] [illegible] the flushing of toilets to the minimum whenever practical.

(c) Limit lawn watering to only when grass shows signs of withering and apply [illegible] as slow as possible to achieve deep penetration.

(d) Limit shrubbery watering to the minimum [illegible] household water when possible.

(e) Limit car washing to the minimum.

(f) Limit wash downs of outside areas such as sidewalks, patios, driveways, or other similar purposes.

(g) Limit hours of operation of water-cooled air-conditioners if possible.

(h) Use disposable dishes and utensils, both for residential and commercial purposes, where feasible.

Stage III, Mandatory Conservation.

Customers shall be encouraged to [illegible] [illegible] of Stage I and II, and [illegible] of the conservation effort shall be [illegible] [illegible] the following mandatory measures [illegible] [illegible]:

(a) Water lawns, grass, trees, shrubbery, flowers, golf greens or vegetable gardens except between 5:00 P.M. - 12:00 midnight on Wednesday and Saturday;

(b) [illegible] [illegible] into wading pools or swimming pools except to the extent necessary to replenish losses due to evaporation or spillage, and [illegible] operation of chemical feed equipment.

(c) Use water to wash down outside areas such as sidewalks, patios, driveways, or for other similar purposes.

[illegible] [illegible] water into any decorative fountain, pool or pond except where water is recycled.

(e) Serve water in a restaurant or similar establishment except upon request.

(f) Use water [illegible] [illegible] [illegible] [illegible] by waste water.

[illegible] [illegible] [illegible] of [illegible] vehicle except where [illegible] (10) gallons or less of the [illegible] is [illegible], or where [illegible] [illegible] well water system is used.

Provided, however, any person may secure [illegible] [illegible] from the City Manager or his designee [illegible] [illegible] [illegible] in the Stage III mandatory conservation measures [illegible] [illegible] be shown to the Manager's satisfaction that use of water pursuant to conditions prescribed by the City Manager in the license will result in a [illegible] or greater saving of water. Any license issued pursuant to this provision (1) shall be in the possession of the licensee whenever water is used contrary to the Stage III mandatory conservation measures, and (2) is subject to amendment or revocation by the City Manager at any time for good cause.

DURHAM CITY CODE

CITY OF DURHAM'S
WATER CONSERVATION MEASURES IN EFFECT AT STAGE III
(MODERATE MANDATORY CONSERVATION)

1. No watering of lawns, shrubbery, flowers, golf greens or vegetable gardens except after 5:00 P.M. on Wednesday and Saturday.

2. No water to be introduced into swimming pools except to the extent necessary to maintain operation.

3. No washing down of outside areas such as sidewalks, patios or driveways, or other similar purposes.

4. Do not introduce water into any decorative fountain pool or pond except where the water is recycled.

5. No serving of water in a public restaurant or similar establishment except upon request.

6. Do not use water for any unnecessary purpose or intentionally waste water.

7. Do not wash the exterior of a motor vehicle except where fifty (50) percent or more of the water is recycled or where a private well water system is used.

CONTINUED VIOLATION WILL RESULT IN WATER SERVICE BEING DISCONTINUED

In addition to the above mandatory measures, the following voluntary measures are encouraged in order to further reduce water consumption:

1. Check for leaks in toilets by putting a few drops of food coloring in the storage tank. If the color comes through to the toilet bowl without flushing, the toilet needs adjustment or repair.

2. Repair leaking faucets whenever they develop.

3. Store drinking water in the refrigerator to avoid trying to run it cool at the the tap, where possible.

4. Use shower for bathing or reduce the depth of water used for tub baths. Limit showers to four (4) minutes.

5. Refrain from running faucets while shaving, rinsing dishes or brushing teeth.

6. Install water flow restrictive devices in shower heads.

7. Install water-saving devices such as plastic bottles or commercial units in toilet tanks.

8. Review water uses and where feasible install recycle systems, particularly commercial and industrial customers.

9. Limit use of clothes washers and dishwashers, and when used, operate fully loaded.

10. Limit flushing of toilets by multiple usage.

11. Limit car washing to the minimum.

12. Limit hours of operation of water-cooled air conditioners if possible.

13. Use disposable dishes and utensils, both for residential and commercial purposes, where feasible.

Stage IV. Severe Mandatory Conservation.

Customers shall be encouraged to observe the conservation measures in Stages I and II and required to continue observing the mandatory requirements in Stage III. The level of the conservation effort shall increase to require the following additional mandatory measures. No person shall:

(a) Water or sprinkle any lawn, grass, trees, or golf greens.

(b) Water any vegetable garden or ornamental shrubs except during the hours of 3:00 P.M. and 9:00 P.M. on Saturday.

(c) Fill any wading pool or swimming pool or replenish any filled pool except to the minimum-essential for operation of chemical feed equipment.

(d) Make non-essential use of water for commercial or public use.

(e) Operate water-cooled air conditioners or other equipment that do not recycle cooling water, except when health and safety are adversely affected.

Stage V. Stringent Mandatory Conservation.

Customers shall be encouraged to observe the conservation measures in Stages I and II and required to continue observing the mandatory requirements in Stages III and IV. The level of the conservation effort shall increase to require the following additional mandatory measures. No person shall:

(a) Use water outside a structure except in an emergency involving fire.

(b) Operate evaporative air conditioning units which recycle water except during the operating hours of the business.

(c) Use any swimming pool or wading pool.

(d) Wash any motor vehicle, including commercial washing unless a private well is used.

In addition to the conservation measures enumerated above customers shall use plates, glasses, cups and eating utensils that are disposable.

Stage VI. Rationing:

Customers shall be encouraged to observe conservation measures in Stages I and II and required to continue observing the mandatory requirements of Stages III, IV and V. The level of the conservation effort shall increase to require the following mandatory measures:

(a) Fire protection will be maintained, but where possible, tank trucks shall use raw water.

(b) All industrial uses of water shall be prohibited.

(c) All other uses of water will be limited to those necessary to meet minimum health and safety needs of the customers as determined by the City Manager upon consultation with the Director of Water Resources in light of conditions present.

Failure to act in accordance therewith or use of water in any manner or attempt to evade or avoid water rationing restrictions, shall be unlawful.

[illegible]

AN ORDINANCE PROVIDING FOR CONSERVATION OF WATER DURING A WATER SHORTAGE, AND FOR RESTRICTIONS ON THE USE OF WATER DURING MORE SEVERE SHORTAGES (86-O-70)

WHEREAS, University Lake provides the primary source of raw water from which the Orange Water and Sewer Authority supplies water to the Town of Chapel Hill, and

WHEREAS, the level of said lake indicates the amount of reserve water available and the need to conserve water, or restrict its use, and

WHEREAS, it is essential for the protection of the health and safety of the citizens of Chapel Hill that restrictive measures be imposed upon the use of water supplied within the Town of Chapel Hill and the surrounding territory through the facilities of the Orange Water and Sewer Authority, in the event the reserve **CHAPEL HILL CITY CODE** [illegible] below normal to critical levels.

NOW, THEREFORE, BE IT ORDAINED by the Town Council of the Town of Chapel Hill:

SECTION I.

That the Council hereby amends Chapter 11 of the Code of Ordinances by adding a new Article X as follows:

Section 11-101. Water Shortage Deemed In Light of Reserve Water Supply

A water shortage shall be deemed to exist when the reserve supply available through the facilities of the Orange Water and Sewer Authority shall have reached the point where the reserve supply has been so reduced that the citizens cannot be supplied with water to protect their health and safety without curtailing substantially the water demand.

Section 11-102. Proclamation of Water Shortage

In the event of a water shortage in any of the five degrees of severity hereinafter set forth in the Town Water Supply threatening the health and safety of the citizens of the Town, the Mayor of the Town of Chapel Hill is authorized, empowered, and directed to issue a public proclamation declaring to all persons the existence of such state and the severity thereof, and in order to more effectively protect the health and safety of the people within the Town of Chapel Hill, to place in effect the restrictive provisions hereinafter authorized.

Section 11-103. Compliance Required in the Event of Shortage

[illegible] the Mayor issues any such proclamation described in Section [illegible] and [illegible] that event it shall be unlawful for any person, firm, or corporation, to use or permit the use of water from the water system within the Town of Chapel Hill supplied through the facilities of the Orange Water and Sewer Authority for any of the purposes hereinafter set forth until such time as this Ordinance be amended or repealed, or until the Mayor, by public proclamation, has declared certain provisions no longer in effect. In exercising this discretionary authority, consideration shall be given to: water levels of available sources of supply; available/usable shortage on hand; drawdown rates; the projected supply capability; outlook for precipitation; daily water use patterns; and availability of water from other sources.

In light of the many benefits that can be derived by conserving water, all residents, businesses and institutions in the community should follow water conservation practices, regardless of the time of year or whether or not a water shortage exists. Water conservation should be followed during all phases of construction related activities. Where appropriate, water needed should be obtained from supplemental sources and non-essential construction-related activities which require water should be delayed until such time as the water emergency has ended.

Section 11-104. Restrictions Applicable Various Water Levels at University Lake

The severity of the water shortage shall be determined by the level of University Lake, and the restrictive measures in effect at each stage are as follows:

A. In the event the water level of University Lake declines to a level of 347 feet above mean sea level (24 inches below full) a stage I of water shortage ALERT shall be deemed in effect, and the following voluntary water restrictions imposed: may be declared

1. An extensive publicity campaign will be initiated using public media and specialized methods to inform the public of an impending water shortage.

2. Residential conservation measures will be encouraged and recommended including the following:

a. Use shower for bathing rather than bathtub and limit shower to no more than four (4) minutes.

b. Limit flushing of toilets by multiple usage.

c. Do not leave faucets running while shaving or rinsing dishes.

d. Limit use of clothes washers and dishwashers and when used, operate fully loaded.

e. Limit lawn watering to that which is necessary for plants to survive.

f. Water shrubbery the minimum required, reusing household water when possible.

g. Limit car washing to the minimum.

h. Do not wash down outside areas such as sidewalks, patios, etc.

i. Install water flow restrictive devices in shower heads.

j. Use disposable and biodegradable dishes.

k. Install water saving devices such as bricks, plastic bottles or commercial units in toilet tanks.

l. Limit hours of operation of water-cooled air conditioners.

3. It is recommended that water supply line pressure reducing valves be set to the minimum necessary for effective operations of fixtures and equipment.

4. Conservation in public buildings, institutions, dormitories, etc. is encouraged by reducing pressure at plumbing fixtures, by installation of restricting devices and shutting down on water flow control devices, and by only periodic flushing of urinals.

5. All residents, businesses and institutions are requested to temporarily delay new landscape work until the work shortage has ended.

6. Local governing bodies will utilize untreated or reclaimed water for street washing, landscape irrigation, and other appropriate purposes to the extent practical and will implement in their facilities the water conservation measures required under a stage II WARNING of the ordinance.

may be declared

B. In the event the water level of University Lake declines to the level of 346 feet above mean sea level (36 inches below full), a stage II water shortage WARNING shall be deemed in effect, and in addition to the restrictions heretofore imposed, the following moderate mandatory water restrictions shall be in effect. It shall be unlawful to use water from the public water system supplied by Orange Water and Sewer Authority for the following purposes:

1. To water lawns, grass, shrubbery, trees, flower and vegetable gardens except as follows:

Customers located to the south of the centerline of NC 54 West, Main Street in Carrboro, Franklin Street, and US 15/501 Boulevard may water lawns, grass, shrubbery, trees, flower and vegetable gardens on Saturday morning between the hours of 6:00 am and 9:00 am.

Customers located to the north of the centerline of NC 54 West, Main Street in Carrboro, Franklin Street, and US 15/501 Boulevard may water lawns, grass, shrubbery, trees, flower and vegetable gardens on Sunday morning between the hours of 6:00 am and 9:00 am.

Such watering is to be done by hand-held hose or container or drip irrigation system.

2. To fill newly constructed swimming and/or wading pools or refill swimming and/or wading pools which have been drained. A minimal amount of water may be added to maintain continued operation of pools which are in operation at the time the provisions of a stage II WARNING are placed into effect.

3. To operate water-cooled air conditioners or other equipment that does not recycle cooling water, except when health and safety are adversely affected.

4. To wash automobiles, trucks, trailers, boats, airplanes, or any other type of mobile equipment, including commercial washing.

5. To wash down outside areas such as streets, driveways, service station aprons, parking lots, office buildings, exteriors or existing or newly constructed homes or apartments, sidewalks, or patios, or to use water for other similar purposes.

6. To operate or introduce water into any ornamental fountain pool or pond or other structure making similar use of water.

7. To serve drinking water in restaurants, cafeterias, or other food establishment, except upon request.

8. To use water from public or private fire hydrants for any purpose other than fire suppression or other public emergency.

9. To use water for dust control or compaction.

10. To use water for any unnecessary purpose or to intentially waste water.

The owner or occupant of any land or building which receives water from Orange Water and Sewer Authority and that also utilizes water from a well or supply other than that of Orange Water and Sewer Authority shall post and maintain in a prominent place thereon a sign furnished by Orange Water and Sewer Authority giving public notice to the use of the well or other source of supply.

may be declared

C. In the event the lake level of University Lake declines to the level of 344.5 feet above mean sea level (54 inches below full), a stage III water shortage DANGER shall be deemed to exist, and in addition to the restrictions heretofore imposed, the following severe mandatory water restrictions shall be in effect. It shall be unlawful:

1. To water or sprinkle any lawn.

2. To water any vegetable garden or ornamental shrubs except during the hours of 6:00 a.m. to 9:00 a.m. on Saturday. Such watering is only to be done by hand-held hose or container or drip irrigation system.

3. To make any non-essential use of water for commercial or public use, and the use of single service plates and utensils is encouraged and recommended in restaurants.

may be declared

D. In the event the level of University Lake declines to the level of 343 feet above mean sea level (72 inches below full), a stage IV water shortage emergency shall be deemed to exist and in addition to the restrictions heretofore imposed, the following stringent mandatory water restrictions shall be in effect. It shall be unlawful:

1. To use water outside a structure for any use other than an emergency use involving fire.

2. To operate an evaporative air conditioning unit which recycles water except during the operating hours of the business.

3. To introduce water into any swimming pool.

may be declared

E. In the event the level of University Lake declines to the level of 341 feet above mean sea level (96 inches below full), a stage V water shortage CRISIS shall be deemed in effect, and a system of water rationing shall be put in effect in addition to all previously imposed restrictions. In the event of water rationing in which water will be supplied in the minimal quantities required for the health, welfare, and safety of the citizens in accordance with a program determined by the Orange Water and Sewer Authority:

1. It shall be unlawful to fail to act in accordance therewith or use water in any manner or attempt to evade or avoid such water rationing restrictions.

2. Fire protection will be maintained, but where possible tank trucks shall use raw water.

Section 11-105. Penalties.

Any violations of the provisions of the Ordinance shall constitute a misdemeanor punishable upon conviction by a fine not exceeding FIFTY DOLLARS ($50.00) or imprisonment not exceeding thirty (30) days as provided by General Statute Section 14-4 and in addition thereto such violation may be enjoined and restrained as provided in General Statute Section 160A-175.

Section 11-106. Injunctive Remedies.

Pursuant to the provisions of General Statute Section 160A-193, the injunctive remedies therein provided shall be applicable for the summary abatement or remedying of appropriate conditions dangerous or prejudicial to the public health both within the town limits of the Town of Chapel Hill and within one mile thereof and the expense thereof assessed as therein provided.

Section 11-107. Severability.

If any section, subdivision, clause, or provision of the Ordinance shall be adjudged invalid, such adjudication shall apply only to such section, subdivision, clause, or provision so adjudged, and the remainder of this Ordinance shall be deemed valid and effective.

SECTION II

All Ordinances and clauses of Ordinances in conflict herewith are hereby repealed.

SECTION III

This Ordinance shall be in full force and effect from and after its adoption.

This the 22nd day of October, 1984.

AGENDA #8

MEMORANDUM

TO: Mayor and Council

FROM: David R. Taylor, Town Manager

SUBJECT: Proposed Water Conservation Ordinance

DATE: October 8, 1984

Attached for your consideration is a revised water conservation ordinance prepared by the Orange Water and Sewer Authority.

An issue paper by the OWASA staff, a copy of the present ordinance, and a cover letter from the Executive Director of OWASA are also attached. A representative of the OWASA administration will be prepared to make a presentation at the meeting Monday night.

Proposed Changes

Two key changes proposed by OWASA are:

- Earlier "trigger levels" for imposing restrictions when the level of University Lake drops:

| Stage | Lake Level at which restrictions are triggered Under Present Ordinance | Usable Water Storage | Recommended Trigger Level | Usable Water Storage |
|---|---|---|---|---|
| Alert - Stage I | 36" Below | 350 MG | 24" Below | 400 MG |
| Warning II | 48" Below | 300 MG | 36" Below | 350 MG |
| Danger III | 72" Below | 200 MG | 54" Below | 275 MG |
| Emergency IV | 96" Below | 124 MG | 72" Below | 200 MG |
| Crisis V- | 132" Below | 25 MG | 96" Below | 125 MG |

(MG = million gallons)

- Under Stage II (Warning) restrictions, Chapel Hill residents south of Franklin Street and Durham Boulevard would be allowed to water lawns and gardens only between 6 and 9 am on Saturdays.

  Residents to the north would be allowed to do this watering only between 6 and 9 am on Sundays.

  The Town's ordinance now allows this watering Town-wide under Stage II conditions between 4 and 9 pm on Saturdays. The change is intended to even out demand and thereby reduce the risk of sharp increases in water demand.

(over)

The OWASA staff's issue paper reviews the changes in more detail.

## Discussion

Average treated water use has increased from 4.71 MGD when the present ordinance was adopted in 1977 to about 6.0 MGD in 1984.

Although the OWASA system appears likely to begin drawing water from a temporary dam at Cane Creek by 1986, we think that the proposed restrictions are reasonable and prudent, even if they do not become necessary.

Recommendation by OWASA Board of Directors: That Council adopt the following ordinance.

Manager's Recommendation: That Council adopt the following ordinance.