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An Assessment of Municipal and Industrial Water Use Forecasting Approaches

Water Conservation and Supply Information Transfer and Analysis Program

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AN ASSESSMENT OF MUNICIPAL AND INDUSTRIAL WATER USE FORECASTING APPROACHES

by

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A Report Submitted to the

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PREFACE

The planning and management of urban water resources are increasingly constrained by primarily four major forces. First, there are environmental constraints in the procurement of additional supply. Second, a new set of problems have been created with the passage of recent laws and regulations. Institutional and legal problems of interbasin transfers have proliferated, and public concern for environmental quality has resulted in the new legislation, such as the Federal Water Pollution Control Act Amendments (1972), the Safe Drinking Water Act of 1974, and the Clean Water Act of 1977. Third, the costs of water resource development have been rising rapidly, exacerbated by an increase in energy costs and the costs of money. Fourth, the demand for urban water continues to rise, especially in those urban areas experiencing rapid growth as in the southwestern United States.

One consequence of those trends has been the need to develop new techniques of planning and methods of evaluation, such as the formulation and recent revision of the *Principles and Standards for Planning Water and Related Land Resources* by the U. S. Water Resources Council and the *Planning Process: Multiobjective Planning Framework* by the U.S. Army Corps of Engineers. More recently and specifically has been the development of a procedure to evaluate the role of conservation in municipal and industrial water supply planning which has served to broaden the focus from supply-side measures to include the opportunities of demand reduction.

The potential savings from precision in estimating future urban water use are obvious. And, because of the need to predict the effectiveness of potential water conservation measures, new and more responsive approaches of disaggregated demand forecasts are mandatory.

The purpose of this study is to assess current water use forecasting practice in the U. S. Army Corps of Engineers and to recommend those additional approaches which best satisfy current requirements. To accomplish these objectives, this report presents the findings of a three-prong investigation: (1) identification of current needs for improved forecasting approaches in light of the current requirements; (2) review and assessment of current forecasting approaches; and (3) recommendation of the most appropriate forecasting approaches which meet the identified needs and satisfy current requirements. Data were obtained from personal interviews with field planners in 6 districts and 3 divisions, from a questionnaire to 35 districts and 11 divisions, and from the analysis of 27 Corps studies that had forecasted demand.

The report is not a primer on water use forecasting, nor does it offer details of any specific techniques. It is, instead, a description of the state of the art as contrasted to current practice, with recommendations for changes in practice, where warranted.

We are grateful for the generous and thoughtful cooperation of the many participants in this study. We are indebted to those who so carefully completed the questionnaire and thereby provided us with information fundamental to the conclusions of this report. Likewise, we wish to express our gratitude to more than twenty district and division planners who allowed us to explore in greater depth, in personal interviews, the problems that emerged from the mail questionnaire. Finally, the guidance provided by the OCE Water Conservation Task Force was of fundamental importance: in particular, we wish to acknowledge the assistance of Donald Duncan and

Kyle Schilling, whose questions turned each small success into a new challenge. Detailed reviews of the various task reports were coordinated by the project monitor, Morris William Clark. All of these individuals contributed importantly to the interpretation of the data, the conclusions, and the recommendations.

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SECTION I

INTRODUCTION

FORECASTING WATER USE

The provision of municipal and industrial water supplies requires engineering intervention in the natural hydrologic cycle. Dams may be required to provide reservoirs which smooth natural fluctuations in streamflows, or ground water aquifers may be used as natural reservoirs; channels, pipelines, and pumping stations are required to transfer water from sources to points of use; water treatment plants are required to render natural water potable and palatable; used water must be collected, treated and discharged back into natural water bodies.

Although complete data are not available, partial information suggests that the construction of these facilities requires approximately $15 billion in new investment each year (federal, state, and local government as well as industry) (Boland, 1980). This total establishes municipal and industrial water supply/wastewater disposal as one of the several largest industries in the United States. The federal government is a major participant in this industry, planning and financing many major water supply projects (although costs may be ultimately borne by users) and accounting, through grants and direct expenditures, for almost 50 percent of all wastewater-related outlays.

A major factor in determining the magnitude of these costs is the quantity of water which must be supplied, treated, distributed, collected, treated, and disposed of each year. In particular, the character, size, and timing of the engineering works required in the future are largely dependent upon expected levels of water use. The planning of such facilities, therefore, requires that future water use levels be forecast. Since the planning, design, and construction of water facilities are an inherently slow process, and since most such facilities are relatively long-lived, water use is customarily forecast over long periods — 20, 30, 50, or even 100 years. Such forecasts are an indispensable prerequisite to any water supply plan (or wastewater disposal plan), and their importance increases with the implementation of water conservation policy.

A water use forecast is a conditional prediction of the level of water use at some future time. The forecast may refer to the average level of use in a given year (average day water use), or to any of a number of measures of variation in water use (summer season use, maximum month use, maximum day use, peak hour use, etc.). Forecasts are conditional because they contain assumptions regarding future levels of water using activities, future relationships between water use and the level of water using activities, future economic conditions, future prices, etc. Any particular forecast is an estimate of the most likely level of future water use, *given* that all of the underlying assumptions prove correct. Accordingly, forecasting methodology is as much concerned with finding the appropriate assumptions as with calculating expected water use given the assumptions.

The water use forecast, in turn, becomes one of the assumptions on which the water supply plan is predicated. In most cases, facilities will be designed, sized, and timed such that the present value cost (in economic and/or environmental terms) of the plan is minimized and future water demands are met as they are expected to occur. If actual future water use turns out to be greater than forecast, the planned facilities will be inadequate. If actual future water use is less than forecast, the planned facilities will exceed requirements. In either case, excess economic and environmental costs will be incurred. In the former situation, facilities will be pressed beyond economic loadings and/or service lives and water supply deficits may occur, imposing private costs on water users. In the latter case, too-early construction and over-sizing will result in excess and/or premature economic and environmental costs.

Water use forecasts can be in error for many reasons. Inappropriate or unintended assumptions may be made in determining the parameters of the forecast — future population may be incorrectly projected, changes in the mix of household types may be omitted, changes in the real level of water price may be ignored, etc. Other errors may occur in determining the relationship between the values of these parameters and the level of water use. Conservation efforts may alter the amount of water used in future households, for example, even though all other factors remain the same. Whatever the cause, all forecasting errors produce excess economic and environmental costs, costs which may be avoided through the use of improved forecasting approaches.

THE NEED FOR IMPROVED APPROACHES

The U.S. Army Corps of Engineers plans, designs, and constructs large water resource development projects which typically include water supply as one of a number of purposes. Although the allocated cost of the water supply portion of the project is usually borne by local beneficiaries, the scale and timing of the entire project is often dependent upon the water use forecast. The Corps employs a structured, multi-stage planning process, which identifies needs and possible solutions in a series of increasingly detailed iterations. Area-wide studies are also performed, which result not in a specific project plan but in a general water resource management plan. The Corps provides technical assistance to state and local governments, upon request, in a range of areas, including the preparation and/or review of water use forecasts.

Prior to 1978, federal agencies such as the Corps directed their efforts to efficient development and management of water supply; demand-side management efforts were left to state and local agencies actually engaged in providing water services. Beginning in 1978, in response to public concerns, federal water resources policy has been significantly reformulated. Potential water conservation measures must now be identified and analyzed with the same rigor, and according to the same criteria, as potential water supply measures. Where the result of the planning process was once a "water supply plan", it is now a "water supply/conservation plan", combining those water supply and water demand management measures which provide the largest net increase in the selected objective function.

One consequence of this broadening of the Corps' planning perspective has been to highlight some of the deficiencies of past water use forecasts. These forecasts utilized, in many cases, relatively simple methods. Most factors likely to affect future water use were not explicitly considered, and the possible introduction of water conservation or other demand management measures was rarely contemplated. Because of the strict division of roles (supply-side vs. demand-side planning), Corps planners were sometimes not in a position to effectively review, or to substantially revise forecasts provided by state and local entities.

Present policy requires the Corps to consider a wide range of management measures in an attempt to identify the most desirable plan for each situation, without artificial limitation to those strategies which include only supply augmentation measures. This responsibility imposes a further requirement: that of preparing a responsive and accurate water use forecast. Such a forecast is responsive if it accounts for possible changes in the factors which explain water use as well as changes in the water use functions themselves. This means going beyond simple reliance on future population estimates: forecasts must account for changes in the housing mix, changes in the structure of commercial and industrial water use, changes in future real prices and water and wastewater service, and the implementation of water conservation measures. Since individual water conservation measures frequently affect specific sectors of water use, forecasts may require separate treatment of separate user classes. Such forecasts are accurate if they succeed in explaining future water use in terms of the causative factors, so that forecasts provide close approximations of actual future water use.

OVERVIEW OF REPORT

This report presents the results of a three-part investigation of appropriate conceptual approaches to forecasting municipal and industrial water use. The first study task, reported in Section II, reviews the needs for improved approaches, as revealed by contrasting current forecasting practice with emerging requirements.

In order to determine pre-1980 forecasting practice (prior to recent changes in forecasting requirements), field planners in each of the districts and divisions were asked to provide certain information regarding forecasting approaches during the past five years. Copies of the relevant reports were obtained and reviewed. The practices of six districts and three divisions, selected by a joint OCE-IWR task force, were further reviewed in a series of personal interviews conducted in the field offices. The results of the mail survey appear as Appendix A, and summaries of the personal interviews are contained in Appendix B.

The requirements for water use forecasts are obtained from a review and synthesis of applicable standards, procedures, regulations and guidance governing water supply planning in the Corps of Engineers, as revised to December 1980. Requirements are framed with particular attention to the wide range of planning roles which the Corps may assume from time to time; where planning is conducted in stages, requirements differ from stage to stage as the level of planning detail increases.

Finally, the description of current practice is contrasted to the requirements to obtain a detailed list of forecasting needs, which must be met by the application and/or development of improved forecasting approaches. This comparison also reveals instances in which current practice fully satisfies relevant requirements, so that no new approaches are required.

The second study task, reported in Section III, comprises a review and assessment of existing forecasting approaches. The water resource and economics literature has been searched for all relevant reports and papers, and these have been subjected to a structured review. As a partial result of this review, an annotated bibliography of water use forecasting literature has been prepared, and published as a separate report. Distinct forecasting approaches, as they are found in the literature, are categorized and summrized according to their particular characteristics. The system of categories used in this task corresponds to that employed for summarizing needs in the first part of the study. This permits ready identification of those approaches which appear to meet specific needs.

Finally, in Section IV, the tabulations of needs and available approaches are used to determine which approaches may best satisfy specific needs. Particular attention is given to approaches that have been applied under field planning conditions. Information and insights obtained during the first part of the study are used to assess the feasibility of suggested approaches, especially with respect to such considerations as data availability, sensitivity to data errors, flexibility, etc. The conclusions, in turn, lead to a set of recommendations for forecasting practices which will fully meet current requirements.

SECTION II

IDENTIFICATION OF NEEDS

PRE-1980 FORECASTING PRACTICE

Description of Study

Normal practice for forecasting municipal and industrial water use has been reviewed with the assistance of field planners in 35 Corps districts, and 11 divisions. Most of these planners (33 districts and nine divisions) were requested to complete and return a written questionnaire designed to elicit certain key information about forecasting practice. The results of this mail survey, presented in Appendix A, serve to identify the major parameters of current practice, and to suggest a basis for judging the importance of individual issues.

In addition, planners were asked to provide copies of planning reports which contain water use forecasts. Almost half of those responding to the questionnaire submitted reports, and these were subjected to further analysis by the contractor. Results of this analysis are also presented in Appendix A.

Selected field planners (from six districts and three divisions) were visited by the contractor and interviewed in depth on forecasting practices, and on their perception of the need for improved methods. These interviews, described in Appendix B, provide much of the perspective and detail which appears in the following sections. In some cases, copies of relevant planning reports were obtained in the course of these interviews. The reports were subjected to the same analysis as those obtained by mail, and the results are combined with those reported in Appendix A.

Forecasting Practice

ROLE OF FORECASTS

Purpose

Water use forecasts are employed in a wide variety of planning studies conducted by the Corps of Engineers. By far, forecasts have been most frequently used in the planning of the water supply purpose of a multi-purpose water resource project, usually involving the construction of a major impoundment. Water use forecasts are also used in reallocation studies for multi-purpose projects already authorized or completed. Urban studies and river basin studies normally include water use forecasts. At the request of individual states, some districts have provided water use forecasts as parts of technical assistance reports.

Most forecasts are used as the basis of design of water supply facilities. Prior to 1980, these facilities have usually been major impoundments. Conveyance, treatment, and/or distribution facilities have only occasionally been considered. In the case of reallocation studies and some types of technical assistance studies, however, water use forecasts may be used to determine operating procedures or to evaluate medium-range adequacy of existing supply sources.

Requirements

The Corps has provided little specific guidance for water use forecasting, beyond that contained in EM 1120-2-101 and EM 1120-2-118 which applies to planning generally, and to forecasting certain demographic and socioeconomic variables (population, employment, etc.) which may be used in water use forecasts. The U.S. Water Resources Council, in *Principles and Standards for Water and Related Land Resources Planning,* as it existed prior to 1980, set standards for population and employment forecasts which included reliance on OBERS forecasts, unless a departure from these projections could be justified on the basis of local conditions.

As a result of review processes within the Corps, the professional training of field planners, and the continuing training opportunities offered by the Corps, an unwritten consensus as to what constitutes minimum acceptable practice has evidently evolved. This consensus standard has not been articulated by anyone during this study, but is evidenced in the considerable uniformity of methods and approaches. So, while formal standards for forecasting methods do not exist, widely understood informal standards appear to have been in force.

Origin of Forecast

The addition of a water supply purpose to a multi-purpose water resource project is dependent upon the willingness of local agencies to contract for the purchase of the storage volume allocated to water supply. In such cases, it would seem essential that the water use forecast employed in the planning process be either one developed by the local agency, or one with which that agency fully concurs. It was expected, therefore, that many districts would use forecasts prepared by state and local agencies. Survey results reveal, however, that locally prepared forecasts were used in less than 20 percent of all cases.

Additional information obtained from the personal interviews suggests that locally prepared forecasts may, in many additional cases, form the basis of forecasts completed by the Corps. Local projections of population may be modified to agree with OBERS projections; water use coefficients may be changed for consistency; the forecast period may be increased; other alterations may be made to provide a multi-jurisdictional forecast which subsumes the individual forecasts for each of the jurisdictions. While this final forecast is clearly a Corps product, it relies heavily on previous efforts by local agencies, and is likely to be supported by those agencies.

In spite of necessary reliance on local sources, and of the need to maintain the support and concurrence of local agencies, it appears that Corps planners are accustomed to accepting responsibility for the final water use forecast. The degree to which local assumptions are accepted uncritically cannot be determined, and may vary substantially from planner to planner and from study to study. Instances were found where the Corps, or consultants employed by the Corps, prepared forecasts which were at substantial variance with local projections. In other cases, no suitable local forecasts existed, so the Corps forecast was the only one available.

Type and Duration

With few exceptions (some reallocation and technical assistance studies), water use forecasts are long-range projections, usually for 50 years. This follows from their primary role in the design of major facilities. Since these facilities are often large impoundments (storage capacity well in excess of annual inflow), most forecasts address average day water use only.

Other studies, including those involving smaller impoundments, usually lead to forecasts of any of a number of measures of variability in water use. These include seasonal water use, maximum month water use, maximum seven-day water use, and maximum day water use. In a few technical assistance studies, forecasts of average day sewer contribution were also noted.

CORPS-PREPARED FORECASTS

Forecast Methods

Water use forecasts are, almost without exception, carried out by the per capita requirements method, or by some close variant of that method. Many studies forecast municipal and industrial water use as a single aggregate, but the separate projection of industrial water use is not unusual. Further disaggregation by user sector (residential, commercial, etc.), once quite rare, has begun to appear more frequently in the past 2-3 years. Geographic disaggregation is widely used, especially where the forecast covers more than one political jurisdiction.

The per capita requirements method estimates future water use as the product of projected population and a projected per capita water use coefficient. Population projections come from two sources:

1. OBERS forecasts, or interpolations of OBERS forecasts; or
2. Where justified, projections developed by local governments or planning agencies.

When deviations from OBERS forecasts are indicated, it is comparatively unusual for Corps personnel or Corps consultants to prepare population forecasts.

Per capita water use coefficients are usually calculated (for the base year) from the production records of local water utilities. Occasionally, where suitable data do not exist, they may be taken from nearby communities, from national averages, from state water resource planning criteria, or from textbooks. Coefficient values after the base year are projected in one of the following ways:

1. They are assumed constant;
2. They are assumed to change at an arbitrarily assigned rate (such as increasing by one percent per year, etc.);
3. Future values are extrapolated from historic trends, based on water production data; or
4. Future values are extrapolated from regional or national trends.

When industrial water use is separately forecast, it may be estimated on a per capita basis, on a per employee basis, or on other bases. The industrial sector may be disaggregated into a number of industry groups or, where feasible, individual firms may be considered. In the latter case, the industrial forecast sometimes incorporates projections made by representatives of the individual firms.

None of the various methods for forecasting industrial water use seem to predominate: considerable diversity was found. Some districts utilize multi-variate water use models, incorporating number of employees, recirculation ratio, productivity, and other variables. Other methods rely on physical product, on total wages, on gross value originating, on extrapolations of historic water use, and on other variables.

Data Sources

Beyond the use of Census data and OBERS projections, most districts rely on local government and utility sources for much of the necessary data. Primary data collection by Corps planners or their consultants is quite rare.

The most common instance is probably the occasional contact between Corps planners and representatives of industrial firms, where data may be sought on future expansion plans, past water use levels, etc. Most socioeconomic and demographic data are obtained from state and local planning agencies; water use data are usually obtained from water utilities. The water use data collected are likely to be limited to production data, usually in the form of annual totals. The analysis of billing data, essential to the production of forecasts employing sectoral disaggregation, has only been attempted in recent years.

FORECASTS PREPARED BY OTHERS

Forecast Methods

Characterization of forecasts prepared by state and local governments and by water utilities relies mostly on the impressions and recollections of those Corps planners who were interviewed. It appears that these local forecasts almost invariably employ per capita requirements methods of the simplest type: sectoral and/or geographic disaggregations are rarely used. Population forecasts are usually developed locally, and are stated to be frequently in excess of corresponding OBERS projections. Per capita water use coefficients are obtained and forecast by one of the methods listed above. Industrial water use is not always separately forecast; where it is separated, it may be projected by a comparatively simple per capita or per employee method. Forecast periods are often relatively short (10-30 years, for example), and forecasts usually address average day and maximum day water use only.

Data Sources

Locally prepared forecasts typically rely on the same socio-economic and demographic data which would be utilized by Corps planners, although the treatment of these data may differ. Water use data are obtained from water utilities and, as in the case of Corps planning, almost exclusive use is made of production records, rather than billing data.

Problems and/or Deficiencies

Existing forecasting practice relies, for the most part, on aggregate descriptions of water use, which is forecast on the basis of a single water use coefficient (usually water use per capita) whose value may or may not be permitted to change during the forecast period. Where water use varies spatially, geographic disaggregation has been customarily used.

Because sectoral disaggregation is not normally used, forecasts are insensitive to changing sectoral patterns in developing communities, including differential growth rates for multi-unit and single-unit housing. Consideration of specific water conservation measures, which often selectively alter water use by user sector, is frustrated by the absence of sectoral disaggregation.

Since most variables known to affect water use are omitted (such as price, income, family size, irrigable area, weather, levels of commercial and institutional activity, etc.), forecasts are insensitive to any changes from the past relationships existing among these variables. In particular, the sensitivity of future water use to alternate planning assumptions cannot be determined.

Where water supply reliability is to be considered as a decision variable in the planning process, drought management measures must be analyzed for their effectiveness in reducing future water use. As in the case of long-term water conservation, these measures affect individual user sectors in different ways, and cannot be easily evaluated in the absence of disaggregate forecasts.

It should be noted, however, that attempts to develop disaggregate forecasts have been hampered by the general inability of water utilities to produce the analyses of billing data needed to support the development of the necessary forecasting models. Further, the inclusion of additional explanatory variables creates the requirement to forecast future values for those variables, multiplying data requirements in areas where data may not be readily available.

REQUIREMENTS FOR WATER USE FORECASTS

Water Resources Council

BACKGROUND

Prior to 1980, the U.S. Water Resources Council did not provide specific guidance as to water use forecasting procedures or formats. Where population, income, and employment projections have been employed in forecasting water use, however, those projections are required to be consistent with the OBERS projections, unless deviation can be justified on the basis of unique local conditions. The OBERS Series "C" projections were used for this purpose, recently superceded by the OBERS Series "E" projections, which take account of continued low birth rates and recent declines in real income.

The 1980 revisions to the *Principles and Standards for Water and Related Land Resources Planning* include provision for fully integrating consideration of water conservation into the planning process, as well as providing somewhat more specific standards for forecasts generally. The Council has also issued *Procedures for Evaluation of National Economic Development (NED) Benefits and Costs in Water Resources Planning (Level C)*. This procedure provides specific guidance for the preparation of water use forecasts.

PRINCIPLES AND STANDARDS

The following sections are taken from 18 CFR 711, *Principles and Standards for Water and Related Land Resources Planning — Level C*, and apply to the formulation and evaluation of alternative plans for Level C Implementation Studies. They also provide the basic policy for Level C Procedures, described in the following section.

Sec. 711.17 Forecasting

(a) Formulation and evaluation of alternative plans are to be based on the most likely conditions expected to exist in the future with and without the plan. The without-plan condition is the condition expected to prevail if no action is taken. The with-plan condition is the condition expected to prevail with the particular plan under consideration.

(b) The forecasts of with- and without-plan conditions shall use the inventory of existing conditions as the baseline, and are to be based on considerations of the following (including direct, indirect, and cumulative effects) —

(1) The national/regional projections of income, employment, output, and population prepared and published by or for the Water Resources Council;

(2) Other aggregate projections such as exports, land use trends, and amounts of goods and services likely to be demanded;

(3) Expected environmental conditions; and

(4) Specific, authoritative projections for small areas.

Appropriate national and regional projections should be used as an underlying forecasting framework, and inconsistencies therewith, while permissible, should be documented and justified.

(f) Forecasts are to be made for selected years over the period of analysis to indicate how changes in economic conditions and environmental resources are likely to have an impact on problems and opportunities.

Sec. 711.20 Period of Analysis

(a) The period of analysis is to be the same for each alternative plan. The period of analysis is to be the time required for implementation plus the lesser of —

(1) The period of time over which any alternative plan would serve a useful purpose; or

(2) A period not to exceed 100 years.

Sec. 711.21 Risk and Uncertainty — Sensitivity Analysis

(a) Plans and their effects are to be examined to determine the uncertainty inherent in the data or various assumptions of future economic, demographic, social, attitudinal, environmental, and technological trends. A limited number of reasonable alternative forecasts that would, if realized, appreciably affect plan design should be considered.

(b) The planner's primary role in dealing with risk and uncertainty is to identify the areas of sensitivity and describe them clearly so that decisions can be made with knowledge of the degree of reliability of available information.

Sec. 711.50 General

(e) Water conservation is to be fully integrated into plan formulation as a means of achieving NED and EQ objectives. Water conservation consists of actions that will —

(1) Reduce the demand for water;

(2) Improve efficiency in use and reduce losses and waste; and/or

(3) Improve land management practices to conserve water.

A clear contrast is drawn between the above conservation elements and storage facilities. A range of measures that can, over time, balance water demand for various purposes with water availability is to be considered.

(f) Nonstructural measures are to be considered for all problems and opportunities such as those related to water supply, flood damage, power, transportation, recreation, fish and wildlife, etc.

(1) Nonstructural measures are complete or partial alternatives to traditional structural measures for addressing water resources problems and opportunities. Nonstructural measures include modifications in public policy, management practice, regulatory policy, and pricing policy.

(2) A nonstructural measure or measures may in some cases offer a complete alternative to a traditional structural measure or measures. In other cases, nonstructural measures may be combined with fewer or smaller traditional structural measures to produce a complete alternative plan.

PROCEDURES

The following sections are taken from 18 CFR 713, *Procedures for Evaluation of National Economic Development (NED) Benefits and Costs in Water Resources Planning (Level C)*. The procedures are to be adopted by all affected Federal agencies, and used in the development of agency procedures necessary to supplement and implement Council procedures.

Sec 713.35 Planning Setting

(a) Some risk and uncertainty are assumed in nearly every aspect of a water resources project. Some types of risk and uncertainty are dealt with in terms of national planning parameters — for example, ranges of population projections and other principal economic and demographic variables. Other types of risk and uncertainty will be dealt with in terms of project or regional estimates and forecasts. When projects are related to other projects and programs in their risk and uncertainty aspects (i.e., interrelated hydrologic systems) reasonable attempts should be made to see that the same analyses and presumed probability distributions are used for all of them.

(b) The risk and uncertainty aspects of projects are likely to be seen and analyzed differently as planning proceeds from rough screening to detailed project proposals. An effort should be made, therefore, to relate the techniques used in characterizing and dealing with risk and uncertainty to the stage of the planning process.

(c) The resources available for analyzing risk and uncertainty should be allocated to those assessments that appear to be the most important with respect to their effects on project and program design. Rather than assuming in advance that one or another variable is a more important source of risk and uncertainty, the planner should make a thorough effort to determine which variables will be most useful in dealing with measurement errors and natural sources of risk and uncertainty.

Sec. 713.113 Evaluation Procedure: Project M and I Water Use

Future water use shall be projected by sector, in consideration of seasonal variation, and shall be based on an analysis of those factors that may determine variations in levels of water use. Projections shall include the effects of implementing all expected nonstructural and/or conservation measures required or encouraged by Federal, State, and local policies, and by private actions. Care shall be taken to verify that the expected implementation will take place, and to ascertain the probable time of implementation.

(a) Sector analysis. Project future water use for the same time periods as for the supply projections for each of the following sectors: Residential (include indoor use and outdoor uses such as lawn irrigation and car washing); commercial (include water use for retail and wholesale trade, offices, hospitals, schools, medical laboratories, restaurants, service industries, etc.); industrial (include all water used by manufacturing industries as an input in the production process); and additional uses (include public service use — for example, fire protection — and unaccounted-for losses).

(b) Analysis by time of use. Identify seasonal variations in use for each of the above sectors and maximum day use for the system for each season.

(c) Related factors analysis. (1) Identify the determinants of demand for each sector. Use such determinants as price of water and sewer service; income; number and type of housing units and population per unit; industrial mix; and level of economic activity. The variable projection of these factors as well as the extent to which they influence projection of water use in various sectors shall be explained. (2) Determine the relationship expected to exist between future levels of water use and the relevant determinants of water demand. Develop and use a forecast or forecasts of future levels of the determinants to project alternative future water use by sector and explain the choice of the particular forecast used.

(d) Aggregation of projections. Aggregate separate projections for each sector to a single projection by time period. (This shall not, however, be viewed as a deterrent to meeting the needs of each sector by separate alternatives.)

Sec. 713.125 Evaluation Procedure: Problems in Application

A second major problem will arise over the disaggregation of water use by sectors. Some communities do not collect water use data by sectors. Where the system is fully metered, such data can be obtained by coding customer accounts and accumulating data on use for at least one year. Water use by unmetered customers may be estimated by extrapolating experience with similar metered systems, recognizing that unmetered customers face a price of zero. Data and/or forecasts obtained from all sources shall be verified as reliable and reasonable.

Corps of Engineers

BACKGROUND

The Corps of Engineers has provided little specific written guidance that is applicable to the forecasting of future water use. Standard planning manuals have defined the general setting, and have outlined procedures for projecting population, employment, etc., when necessary. Early in 1978, however, the Corps initiated a two-year research effort which led to the publication of a manual of procedures for evaluating water conservation measures in the context of water supply planning. The manual indicates specific requirements which the evaluation of water conservation measures places on water use forecasting procedures, especially with respect to sectoral disaggregation.

The Corps also follows a multi-level, iterative planning process, where project plans are developed in three distinct stages. The differing levels of specificity implied by these stages place differing requirements on water use forecasts, suggesting a hierarchy of methods applying to a range of planning conditions.

MULTI-LEVEL PLANNING

The first stage in the planning process consists of a reconnaissance study, performed in gross detail and intended to reveal the range of available options for solution of the specified problem. The appropriate water use forecasting method employed at this stage would also utilize little detail, and would be based on readily available data. The conventional per capita requirements method, as now practiced by the Corps, appears to fit this need well.

At the second planning stage, specific alternatives are identified and screened to reveal those which show the most promise. A more detailed water use forecast is likely to be required here, incorporating all of the sectoral and geographic disaggregation, as well as explanatory variables, that may be considered ultimately necessary. Tentative estimates of some variables may be employed, however, and not all data collection need be complete.

In the third stage, where the reduced list of alternatives is evaluated and the project report completed, the water use forecast prepared in the second stage would be refined and revised where necessary. Data collection would be completed, and missing data supplied or tentative data replaced.

The same forecasting methods would not be used in each study; they would vary according to study requirements, planning conditions, and data availability. Whatever methods are used, however, there should be a progression from the least detailed procedure to the most detailed, as the planning process moves to completion.

CONSERVATION EVALUATION

Early in 1980, IWR issued a report entitled "The Evaluation of Water Conservation for Municipal and Industrial Water Supply — Procedures Manual." This report describes the concepts, procedures, and measurement techniques which can be used in developing and evaluating water conservation proposals applicable to municipal and industrial uses of water. It is intended to complement the revised *Principles and Standards* and the newly issued *Procedures* of the Water Resources Council.

Section 4-2 of the Procedures Manual lists prerequisites to the analysis of individual water conservation measures. Among these prerequisites is the following:

> (b) Disaggregated Water Demand Forecasts. Forecasts of water use, disaggregated by user sector and season, should be available for the period of analysis. Disaggregation is important for making estimates of the effectiveness of water conservation measures which affect specific types of water use. Water use should be forecasted separately for the following sectors: residential (include indoor uses and outdoor uses such as lawn irrigation and car washing); commercial (include water use for retail and wholesale trade, office, hospitals, schools, medical laboratories, restaurants, service industries, etc.); industrial (include all water used by manufacturing industries as an input to production processes); and additional uses (include public service use — for example, fire protection — and unaccounted-for water). Where possible, further disaggregation should be employed — for example, residential use may be divided into inside and outside components, industrial use may be divided into process water and nonprocess water. Also, water use should be forecasted separately by season (for example, summer vs. winter), either in aggregate or, preferably, by sector. Where disaggregated forecasts are not used, estimates of effectiveness and of beneficial effects may include substantial error.

The Procedures Manual also contains additional description of data requirements and suggested procedures for performing disaggregate water use forecasts.

NEEDS FOR FORECASTING APPROACHES

General Requirements

Forecasting approaches are required which can produce long range (30-100 years) and medium range (10-30 years) forecasts of municipal and industrial water use, using data which are reasonably available, or which can be made reasonably available to Corps planners. Forecasts are required for average day water use and for any of several measures of peak period water use (seasonal water use, maximum month water use, maximum day water use, etc.). Forecasts of contribution to sewer flow may also be needed.

A range of methods should be available so that the forecasting approach can be tailored to planning requirements. Comparatively simple methods should be used in stage 1 planning, while more complex methods may be appropriate to stage 3 planning. Project type and size, data availability, consideration of water conservation measures, and other factors all affect the choice of forecast method. Some methods employ readily available data, others may require data collection programs. Some are relatively simplistic, while others permit the generation of alternative forecasts based on detailed and varied assumptions regarding future conditions. Methods used in project planning may not be identical to those employed in river basin studies, special studies, or in providing technical assistance to states.

Disaggregation

Forecasting approaches may range from no sectoral disaggregation (used in stage 1 planning), to three- or four-sector disaggregation (residential, commercial, etc.), to detailed sectoral disaggregation (single-family vs.

multi-family residential, etc.). At least some sectoral disaggregation is required whenever the effectiveness of existing or proposed water conservation measures must be considered. Sectoral disaggregation also adds greatly to the flexibility of the forecasting method, and is required by the Water Resources Council *Procedures*.

All forecasting methods should be adaptable to geographic disaggregation. Criteria are needed for devising geographic disaggregation methods which improve forecast accuracy and flexibility, rather than simply following jurisdictional boundaries.

Forecasting Models

Appropriate forecasting models are required for all types of sectorally disaggregate forecasting methods. These models should be capable of explaining sectoral water use in terms of selected explanatory variables. Generally, a range of models would be desirable, extending from simple forms with one or two explanatory variables to more complex models. This range would permit accommodation to varying degrees of data availability. All models must be capable of forecasting measures of peak period water use as well as average use. Additional explanatory variables are typically required to explain seasonal and peak water use.

Implementation

All forecasting approaches should be capable of implementation under Corps field planning conditions. Guidance should be available regarding data sources, collection of data not presently available, and the level of forecast complexity that is appropriate in each situation. This guidance should take account of the relative inexperience of any particular Corps planner; it should not assume a high level of expertise in water use forecasting.

Relationship to Current Practice

The mainstream of current water use forecasting practice, as described earlier in this report, does not meet all of the needs given here. The per capita requirements approach usually taken appears to be suitable for stage 1 planning applications. Planning at stages 2 and 3 requires methods more advanced than those customarily used. Some districts and divisions have begun to incorporate procedures which meet some or all of the listed needs. These new procedures are not fully developed, and are not generally known or available to other Corps districts and divisions.

SECTION III

ASSESSMENT OF EXISTING APPROACHES

CRITERIA FOR EVALUATION

Objectives

ACCURACY

If forecasting approaches are to be evaluated and compared, appropriate evaluation criteria must be selected. These criteria can be derived once the objective is agreed upon. Of all possible objectives, the most prominent and frequently mentioned is accuracy. Forecasting approaches should provide forecasts which are accurate statements of future conditions.

Objections have been raised to the notion that accuracy is the sole objective for forecasting approaches, however. For example:

1. Accuracy may be an incomplete appraisal of forecasts — other characteristics, quite independent of accuracy, may be desirable (Ascher, 1978).
2. Emphasis on accuracy alone creates incentives for vague, excessively hedged forecasts (Ascher, 1978).
3. Accuracy is an inappropriate objective for forecasts which are potentially self-fulfilling or self-defeating (Ascher, 1978 and Encel et al., 1976).
4. Accuracy as an objective leads to inappropriate criteria when forecasts may be "right for the wrong reasons" (Encel et al.,1976).

The first objection is self-evident; the possibility of objectives other than accuracy for water use forecasts is discussed in the next section of this report.

The second point hinges on the notion that "right" is not necessarily identical to "not wrong." The pursuit of accuracy should move the forecaster to provide as much reliable information as possible. The avoidance of error, on the other hand, creates incentives to provide as little information as possible, since all forecast values are potentially wrong. Forecasters who wish, above all else, to be "not wrong" will forecast few variables, use simplistic methods, stress qualifying assumptions, and hedge wherever possible. Needless to say, such forecasts do not serve the needs of planning or analysis particularly well.

The third objection arises whenever the audience of a forecast includes those in a position to affect future values of the variables being predicted. When a doctor warns that a patient, maintaining current habits, is likely to have a heart attack, the patient can be expected to adopt some new habits. Such a forecast is self-defeating, in that it stimulates the action needed to frustrate the projected outcome. It has been claimed that water use forecasts are self-fulfilling — the forecast of future higher water use levels stimulates the construction of the facilities which make those levels possible, and at costs which make them probable. The fact that such a forecast may prove accurate, therefore, may comprise a less than complete evaluation of the forecasting approach.

Finally, accuracy may be an inadequate criterion for forecasts which are "right for the wrong reasons." Water use forecasts typically predict future levels of use based on assumed future levels of other variables, such as population. Population may well turn out to be, for example, less than the forecast value. But if per capita water use is greater than expected, the forecast may appear to be "accurate." Any resulting confidence in this forecasting approach would obviously be misplaced.

Yet, none of these objections diminish the importance of accuracy in forecasting. Without accuracy, forecasts lose credibility. Accuracy is the only objective which permits consistent comparisons among all types of forecasting approaches, and for which general propositions regarding the impact of various factors on forecast performance can be made (Ascher, 1978). Reservations about the use of accuracy as a sole objective do not diminish its importance: they underline the need to consider other objectives as well. Forecasts must be evaluated with respect to several objectives, including accuracy.

OTHER OBJECTIVES

Many desirable characteristics apart from accuracy can be listed for forecasting approaches. Ascher (1978) suggests that forecasts should be comprehensive, persuasive, useful, authoritative, provocative, etc. The relative strengths of these objectives vary from application to application, as do the evaluation criteria which they suggest. In the case of water use forecasting as it occurs within the Corps of Engineers, more specific requirements can be offered.

Scope

The scope of water use forecasts has three dimensions: topic, geographic limit, and time perspective (Encel et al., 1976). Topic has to do with which variables, or measures of water use are to be forecast. Many forecasts deal with average day (or total annual) water use alone; others consider seasonal water use, maximum day water use, average day sewer flow, etc. The choice of the specific water users to be considered in the forecast determines the geographic limit. Time perspective refers to the length of the forecast period as well as to the choice of intermediate forecast years. It should be noted that scope is primarily a function of forecasts, not forecasting approaches. Each analyst chooses topic, geographic limit, and time perspective as required in each forecasting application. Forecasting approaches are evaluated in terms of constraints they may impose on the analyst's choice. Specifically, the choice of topic (possibility of forecasting seasonal or maximum day water use, for example) and time perspective (long range vs. short range forecasts) may be constrained by certain forecasting approaches.

System Definition

The water use system is defined in terms of structure (sectors) and components (explanatory variables). The forecasting approach should reflect that system definition. In general, water use systems are assumed to be open systems: some of the factors explaining water use are exogenously determined. Forecasts for such systems may be either absolute (single-number predictions are provided for exogenous variables) or conditional (alternative future values are considered for exogenous variables). Conditional forecasts, sometimes including alternative functional relationships as well as alternative values for explanatory variables, can be described as forecasts for alternative futures. Ascher (1978) notes that such methods are indicated for forecasts involving trends which are potentially controllable by members of the forecast audience (self-defeating or self-fulfilling forecasts), and are frequently desirable for other forecasting applications as well. Conditional forecasts are clearly relevant to water use forecasting.

Another aspect of system definition is the level of disaggregation at which the forecast is to be conducted. In the case of water use forecasts, disaggregation is customarily conducted along sectoral (according to groups of similar water users) and/or geographic (according to political or other subdivision) lines. Since aggregate water use is the sum of uses by many individual users for many individual purposes, aggregate methods will tend to conceal all but the least common denominator among trends. Encel et al., (1976) state that "very highly aggregated forecasts which do not permit systematic checking of the pertinent details are neither good nor bad, but rather are obscurantist."

Evaluation Criteria

The objectives described above form the basis of various criteria which can be used to evaluate specific forecasting approaches. As noted previously, the objectives properly refer to the forecasts, not to the methods used to produce them. The evaluation of methods focuses on constraints which they may place on analysts, preventing the achievement of certain forecasting objectives. While an inadequate method may guarantee an inadequate forecast, it is important to remember that an adequate method does not guarantee an adequate forecast. While necessary, appropriate forecasting approaches are not sufficient. The proper application of those approaches by a competent analyst is required if the objectives of forecasting are to be achieved.

The choice of accuracy as an objective of forecasting creates some empirical difficulties, since accuracy cannot be prospectively determined. It is further pointed out by Encel et al. (1976) that forecasting itself cannot be a strictly scientific procedure, since the future, properly speaking, does not exist. Experience with past forecasts, however, has disclosed characteristics of forecasting approaches and applications which appear to be related to forecast accuracy. These correlates of accuracy have been described by Ascher (1978) and are summarized below. Other forecasting objectives lead to a list of critical issues, presented by Encel et al. (1976) and repeated below, which partly overlap Ascher's criteria. These two viewpoints provide the basis for a set of evaluation criteria appropriate to water use forecasting approaches.

CORRELATES OF ACCURACY

Methodology

The forecast approach chosen should permit the choice of an appropriate scope: the approach should be consistent with the measures of water use to be forecast (topic), the area to be covered (geographic limit), and the forecast period (time perspective). Beyond this requirement, the forecasting approach should incorporate sufficient disaggregation (sectoral or geographic) so that significant trends or relationships are not concealed, and so that systematic checks of accuracy are possible. The forecasting approach should reflect consensus by focusing on the center of informed opinion regarding structure, components, and trends. Also, the role of judgement in the forecast should be appropriate and explicit. As stated above, forecasts, by their nature, cannot be totally objective. Judgement, therefore, is never absent, regardless of approach.

Context

Attention should be given to the structural stability of the forecast approach, and to its complexity. Structural stability refers to the sensitivity of forecast water use levels to possible changes in the functional relationship between water use and its explanatory variables, as well as to unexpected changes in the future values of explanatory variables (departures from trends). The incorporation of disaggregation and multiple explanatory variables, a possible means of dealing with structural instability, creates complexity, which carries its own liabilities (such as data requirements and loss of comprehensibility and credibility).

Sources of Bias

Unintentional bias can be incorporated into forecasts for many reasons. The institutional base of the analyst is one possible source. A Corps planner may have access to certain quantities and types of information on which to base a forecast. A consultant employed by the Corps for the same purpose may find or have access to more or less information. Local agencies may have still different information resources. Analysts in different institutional settings are likely to have had different professional experiences, and may show different preferences for forecasting approaches, and exhibit different degrees of bias in the judgemental aspects of the approach chosen. The analyst's professional training, regardless of institutional setting, may affect these choices as well.

FORECASTING ISSUES

Encel et al. (1976) provide a list of eight critical issues in forecasting, which are summarized below with comments on their application to water use forecasting.

1. Over-selling. Forecasts should not be interpreted as absolute predictions. Rather, they are conditional predictions of what future water use will be provided various assumptions prove to be true. Even then, the predictions are properly stated in probabilistic terms.
2. Determinism. Observed relationships between water use and its explanatory variables are not immune to change as a result of unforeseen influences. Past causality is not guaranteed for the future.
3. Continuity. The near-universal use of trends in forecasting carries with it the assumption of stable underlying mechanisms. Such mechanisms may not exist or, if they exist, they are not necessarily stable.
4. Simplification. Forecasts rely on models, which are simplifications of reality. Simplification is a virtue, provided that the model retains the essential features of reality. Where circumstances require substantial disaggregation, holistic models may be used as a check on sectoral models.
5. Quantification. Two dangers exist: that of not quantifying that which can, and that of quantifying that which cannot. Generally, quantification is tenable where data exist, but it may be untenable in some circumstances where, for example, continuity is doubtful.
6. Inadequate data. Data are inadequate when not all data are available, or when data which are available may be inaccurate or inappropriate.
7. Decision-making context. The forecasting process should be independent of the decision-making process which it serves, yet the needs

of the decision-maker should be fully considered in the form and content of the forecast.

8. Isolationism. Independence from the decision-making process, essential in maintaining maximum objective content, may lead to a form of elitism which substitutes normative judgement for positive observation. Forecasts should state what can happen, not what ought to happen. While these statements are inevitably intertwined to some degree, isolation of the forecaster is likely to increase the danger.

FORECASTING APPROACH EVALUATION

Many different approaches have been used or proposed for water use forecasting. Differences between approaches may be small or large. Furthermore, specific forecasts may incorporate the use of several distinct approaches. In order to provide an evaluation of forecasting approaches, therefore, a limited number of prototypical methods are chosen for description and evaluation. Each prototype is evaluated according to the following criteria:

1. Scope. Any limitations which the forecasting approach may impose on the choice of topic (average day, seasonal, maximum day water use, etc.) and time perspective (long range vs. short range, etc.) will be reviewed.
2. Disaggregation. The suitability of the approach for use in preparing sectorally and geographically disaggregated forecasts will be determined.
3. Multi-variate models. Criteria for the choice of explanatory variables used by the forecasting approach will be noted.

4. Alternative futures. While alternative forecasts can be prepared using any forecasting approach, some methods facilitate the incorporation of alternative assumptions regarding future conditions and relationships. The relative ease of preparing meaningful alternative forecasts will be estimated.

5. Continuity assumptions. As noted above, nearly all forecast approaches imply the existence of some stable underlying process. The nature of the assumed underlying process, and the extent to which it may be presumed stable, will be reviewed.

6. Compatibility. To be useful, forecasting approaches must be compatible with field planning conditions. The data required must be reasonably available to Corps planners, the information produced must match the needs of the planning process, the skill requirement must be consistent with the capabilities of field planners, etc. Wherever possible, comments will be provided with respect to these issues.

EXISTING FORECASTING APPROACHES

General

The list of prototypical approaches which follows excludes many forecasting techniques. Some approaches are conventionally applied to subjects other than future water use, and are not included. Pure judgment forecasts, where future water use is taken as the subjective judgment of one person, are not discussed. Judgmental forecasts comprise simple prediction; there is no attempt to explain water use in the present or in the future, and there is no formal model. Similarly, collective judgment forecasts are omitted.

These forecasts utilize the judgement of a number of individuals, achieving consensus by some means, such as a Delphi process. Also omitted are scenario techniques which do not include formal models but depend upon imagination and intuition to postulate a range of possible future outcomes. Typically, little or no guidance is given as to which outcomes are more likely to occur.

Many forecasting approaches are conceivable. A report by the Center for the Study of Social Policy (CSSP) at Stanford Research Institute (1975) listed 150 distinct forecasting techniques. Most of those listed are not included here for reasons just given, because they have not been used or proposed in the forecasting of water use, or because they are clearly inappropriate for this application. Also, the forecasting approaches discussed here are presented at a different level of detail and according to a different classification scheme from those in the CSSP report.

The prototypical approaches fall into four broad categories: those which consist of simple time extrapolation; those which use a single coefficient; those which use multiple coefficients; and those which attempt a probabilistic description of future water use.

Time Extrapolation

SIMPLE EXTRAPOLATION

Description

Simple time extrapolation considers only past water use records; no other data or information is required. The change in water use over time is extrapolated into the future. The extrapolation may be accomplished by graphical or mathematical means, and the change over time may be assumed linear, exponential, logistic, or of any other functional form.

Evaluation

Scope. This method places no particular limitation on topic; average day and maximum day water use can be extrapolated with equal logic, for example. Whatever inadequacies the method may have in other ways, however, are multiplied as the forecast period grows. Explanatory variables, other than time, are not acknowledged, so future changes in these variables cannot be considered. In general, simple extrapolation is likely to be unsuitable for long-range forecasts.

Disaggregation. In principle, separate extrapolations could be made for user sectors and geographic areas. Unless different functional forms were to be assumed for different sectors or areas, or unless the forecast application required disaggregate results, there would be little point in choosing a disaggregate approach. No additional information would be included or provided, since where water use is assumed to change only with time, the trend of the whole is the sum of the trends of the parts.

Multi-variate models. Simple time extrapolation is inherently a single-variable technique: future water use is a function of time.

Alternative futures. This approach provides no particular assistance in the consideration of alternative futures.

Continuity assumptions. Water use is assumed to be explained by the passage of time. The underlying assumption, therefore, is that the change in water use observed with respect to time in the past will be the change in water use with respect to time in the future. There is no empirical reason to expect such a relationship to be stable.

Compatibility. Simple extrapolations require little data, and the data which they do require (e.g., past water production data) are usually readily available. On the other hand, this technique, even if accurate, provides very little information to the planning process. Consideration of alternative futures is inconvenient, sensitivity to such perturbations as the implementation of water conservation measures is unknown, most trends and factors known to influence water use are ignored, and no indication is given of the probabilistic nature of future water use levels.

OTHER TIME EXTRAPOLATIONS

Time extrapolation may be used for other purposes in the course of preparing forecasts. Where other explanatory variables are used to forecast water use, the future values of those variables may be obtained by simple time extrapolation from past values. Such methods are described in Hittman Associates (1969). Also, in other cases, past values of water use coefficients may be extrapolated to obtain future values. A study by the Baltimore District (1976) used an exponential time extrapolation to project per capita water use. Generally, these applications can be evaluated in a manner analogous to that shown above for time extrapolations of water use.

Single Coefficient Methods

PER CAPITA REQUIREMENTS

Description

The per capita requirements approach estimates future water use as the product of projected service area population and a projected value of a per capita water use coefficient. Population may be projected by various means, but is usually obtained from a more holistic econometric forecast, such as the OBERS forecasts. The per capita coefficient may be assumed fixed over time or it may be projected to change with time. Its value and, where applicable, rate of change may be determined from past water use patterns in the same area, in similar areas, for the region, or for the nation. The coefficient value may also be obtained from reference works, from other studies, or may simply be assumed. Recent studies in the literature which use this method include Hansen et al. (1979) and Tate (1977).

Evaluation

Scope. This method places no limitation on topic or on time perspective. All measures of water use may be forecast by the per capita technique, and the method is used for forecasts applying to long and short periods alike.

Disaggregation. The per capita method is customarily applied to aggregate water use, or to municipal (non-industrial) water use. It may be applied to sectorally disaggregated water use, however (see, for example, Tate, 1977). In this case, per capita coefficients are separately calculated for residential use, commercial use, public use, and sometimes for industrial use. Geographic disaggregation, with coefficients calculated for each of a number of distinct areas, is commonly practiced.

Multi-variate models. The per capita requirements approach is a single-variable technique.

Alternative futures. The approach provides no particular assistance in the consideration of alternative futures.

Continuity assumptions. Water use is assumed to be explained by population alone, with possible provision for temporal change in unit use. The underlying assumptions, therefore, are that water use varies proportionately with population and that the ratio of water use to population changes continuously from the past to the future. Neither the proportionality of water use to population nor the stable behavior of the coefficient is supported by the evidence (Boland, 1978, 1979).

Compatibility. The per capita approach requires relatively little data, and the data are usually readily available. The approach is capable of providing some of the information required by the planning process, even though usual application is characterized by restricted scope and aggregate analysis. Consideration of alternative futures is inconvenient, sensitivity to such perturbations as the implementation of water conservation is unknown, many of the trends and factors known to influence water use are ignored, and no indication is given of the probabilistic nature of future water use levels. This approach has been applied under field planning conditions.

PER CUSTOMER REQUIREMENTS

A variant of the per capita approach substitutes the number of customers (usually measured as the number of connections to the water distribution system) for the service area population. This reflects the empirical fact that water use is better correlated with number of customers than with population served (Boland, 1978). Per customer methods are most frequently used in conjunction with disaggregate forecasts, where they may be applied to non-residential sectors (Ecological Analysts, 1977). The evaluation of this approach is analogous to that given above for the per capita approach.

UNIT USE COEFFICIENT APPROACHES

Description

Additional single coefficient models can be proposed, which explain water use as a function of some variable other than population or number of customers. For the most part, these models are applied to non-residential sectors in a sectorally disaggregated approach (see Hittman Associates, 1969). Industrial water use may be forecast as the product of industrial employment and a per employee use coefficient, for example. Unaccounted-for water use may be forecast as a function of distribution system size, commercial water use may be forecast as a function of retail sales, etc. As in the case of the per capita requirements approach, both the explanatory variable and the coefficient are subject to projection.

Evaluation

Scope. This method places no limitation on topic or time perspective.

Disaggregation. This method is customarily applied to sectorally disaggregated forecasts. It is consistent with both sectoral and geographic disaggregation.

Multi-variate models. The unit use coefficient approach is a single-variable technique.

Alternative futures. To the extent that this approach is implemented in the context of a sectorally disaggregated forecast, and that it results in the introduction of variables in addition to population and/or number of customers, the ability of the overall forecast to reflect alternative future conditions is improved. Many possible future conditions would not be readily represented by this type of model, however.

Continuity assumptions. Water use, possibly for a single sector, is explained by a single variable, with provision for temporal change in the coefficient. It is assumed, therefore, that water use varies proportionately with changes in the selected explanatory variable, and that the coefficient value changes continuously from the past to the future. Where the causal relationship between water use and the chosen variable is strong (e.g., industrial non-process water use and industrial employment), these assumptions may be borne out in the short range, but become more tenuous in the medium-to-long range.

Compatibility. The unit use coefficient approach, like other single coefficient techniques, requires relatively little data. Historical data for the explanatory variable, as well as projections of that variable, may be less readily available than for population or number of customers. The approach is capable of providing a moderate amount of information to the planning process, partly because this approach is typically used in conjunction with sectorally disaggregate forecasting methods. Consideration of alternative futures is improved, although still relatively inconvenient; sensitivity to such perturbations as the implementation of water conservation measures is also assisted by disaggregate analysis; the trends and factors known to influence water use are ignored, with the exception of the single explanatory variable; and no indication is given of the probabilistic nature of future water use levels. This approach has been applied under field planning conditions, especially in the case of industrial water use.

Multiple Coefficient Methods

REQUIREMENTS MODELS

Description

Future water use, either aggregate or sectoral, can be expressed as a mathematical function of two or more explanatory variables. The variables are chosen because of their past correlation with water use, and any number may be included, although more than five or six is unusual. The functional form is chosen to provide an acceptable fit of the model to historic data, and the coefficients are estimated statistically, usually by means of regression analysis. Models used in forecasting may have been estimated on the basis of historic data for the same service area, or they may be based on data for some other area, for the region, or for the nation. Models which do not include the price of water as an explanatory variable are known as requirements models. In order to forecast water use, the values of the explanatory variables must be projected. When these projected values are known, the model is used to calculate forecast water use. Multi-variate requirements models have been reported by Hittman Associates (1969), Burke (1970), Berry and Bonem (1974), Ecological Analysts (1977), Frnka (1979), etc.

Evaluation

Scope. This method places no limitation on topic or time perspective.

Disaggregation. Multiple coefficient requirements methods may be applied to either disaggregate or aggregate forecasts. In the case of sectoral disaggregation, different sets of explanatory variables may be used for each user sector. In the case of geographic disaggregation, each of the explanatory variables must be forecast separately for each geographic area.

Multi-variate models. Attention must be given to the number of explanatory variables included, their identity, and the criterion used in deciding to include them. Variables should be included which describe all factors significantly and causally related to the sector of water use under consideration. In choosing potential explanatory variables, correlation alone is not a sufficient criterion. Many possible variables exhibit high intercorrelation, and spurious correlations are not uncommon. A sound, causal explanation should be available for each variable included. Attention should also be drawn to the implications of not including, for whatever reason, potentially significant variables. For example, requirements models omit price; this fact must be considered in evaluating resulting forecasts.

Alternative futures. The inclusion of additional variables improves the ability of the forecast to reflect alternative future conditions. These conditions can be described, in part, as alternative sets of projections of values for the explanatory variables. When the forecasting approach is sectorally and/or geographically disaggregated, the improvement is correspondingly greater. In this case, structural change can be simulated by altering coefficients and forms of the multi-variate models. When potentially significant variables have been omitted, however, representation of alternative futures may be incomplete; where other variables have been inappropriately included, the forecast consequences of alternative futures may be misleading.

Continuity assumptions. Water use is explained by a multi-variate mathematical expression, having coefficients which are fixed over time. Explicit recognition of the determinants of water use has the effect of reducing the strength of the continuity assumptions: each additional explanatory variable included reduces the sensitivity of the resulting forecast to the assumption of continuity. To the extent that significant variables are omitted, however, the values of those variables and their association with water use are implicitly assumed to continue in the future as they have in the past (or as they did in the area where the model was developed).

Compatibility. The multiple coefficient approach requires substantially more data than any of the forms of the single coefficient approach. Some data may be readily available, but other data may not be. Sufficient information must be available to support projected values for all of the explanatory variables. If the model is to be estimated on local data, those data will include past observations of water use (based on customer billings if sectoral disaggregation is required) and of all of the explanatory variables. If the model is obtained elsewhere, sufficient local data must be available to check calibration. The approach, especially when applied to a disaggregate forecast, is capable of providing considerable information to the planning process. Consideration of alternative futures is facilitated, sensitivity to such perturbations as the implementation of water conservation measures can often be determined when sectoral disaggregation is used, many of the trends and factors known to affect water use can be included, but no indication is given of the probabilistic nature of future water use levels. This approach has been applied under field planning conditions, especially in the case of industrial water use.

DEMAND MODELS

Description

Multiple coefficient demand models differ from multiple coefficient requirements models in one key respect: demand models include the price of water to the user, as well as related economic variables, among the explanatory variables. In most cases, price is accompanied by some measure of or surrogate for disposable personal income. Also, demand models are usually constructed according to econometric methods, where the structure of the model and the list of potential explanatory variables are determined on a strict causality basis. The possibility of improperly included or specified variables is thereby reduced. Attention is usually given to providing as complete a list of explanatory variables as possible, so as to minimize the unexplained variance in the dependent variable (water use). Demand models are described by Howe and Linaweaver (1967), Batchelor (1975), Billings and Agthe (1980), etc. They have been applied to forecasting by Hittman Associates (1969), among others.

Evaluation

The evaluation of multiple coefficient approaches using demand models is nearly identical to that of similar approaches using requirements models. The only exceptions are of degree. Demand models usually contain more complete sets of explanatory variables, and the variables are chosen more carefully. The addition of price and, frequently, income improves the ability of the approach to reflect the effect of alternative futures (which may include changes in the real cost of water supply or changes in the pricing policy of the water utility). Sensitivity to the continuity assumption is further reduced by a more complete list of explanatory variables. Finally, the ability of the approach to reflect the effect of water conservation measures which affect price levels or structure is improved. Demand models have been applied under field planning conditions.

Probabilistic Analysis

STOCHASTIC MODELS

As noted above, the development of multi-variate demand models has the purpose of explaining as much as possible of the variance in observed water use. Even the most successful of these model-building exercises leaves a significant fraction of the variance, perhaps as much as 50 percent, unexplained. If it is assumed that the remaining variance is random and not explainable by relationships with other variables, then water use is said to obey the laws of stochastic processes.

A stochastic forecasting model would include multiple explanatory variables to estimate the mean, or central tendency, of future water use, but would also forecast a probability distribution around that mean. In this way upper and lower bounds, and confidence intervals, can be forecast as well as most likely levels. While the need for explicitly stochastic forecasts has been often stated, there have been few attempts to construct and use stochastic models, and these attempts have been less than fully successful in accomplishing their objectives (e.g., Ecological Analysts, 1977 and Carver, 1978).

Since no clearly defined approaches have been proposed, no evaluation can be offered. A stochastic forecasting approach would, if successful, retain all the advantages offered by the multiple coefficient demand approaches while increasing the information provided to the planning process.

CONTINGENCY TREES

Description

This approach permits the incorporation of additional, non-continuous factors into a base forecast already prepared according to one of the approaches outlined above. As the method is presented by Whitford (1972), alternative futures are based on various non-reversible events which might occur in the future, altering the demand for water. Subjective estimates are made of the effect on water use of each event, should it occur, and of the probability of occurrence. A contingency tree is constructed to show the joint probability for each possible combination of event occurrences or non-occurrences. These assumptions can then be used to construct a subjective probability distribution around the original forecast, which has been based on non-occurrence of all of the postulated events.

Evaluation

Scope. This method places no limitation on topic or time perspective.

Disaggregation. The approach is compatible with disaggregate forecasts.

Multi-variate models. As the factors to be considered are not among those usually considered for inclusion in a multi-variate model, the approach is consistent with the use of such models in the preparation of the base forecast.

Alternative futures. This approach facilitates full and explicit consideration of alternative futures in forecasting water use.

Continuity assumptions. No continuity assumptions are required, except as they may apply to the base forecast.

Compatibility. Little additional data is required beyond that used in the base forecast. The analyst must determine those factors likely to affect future water use, and make subjective estimates of water use effects and probabilities of occurrence. The results provide all of the information contained in the base forecast, as well as additional insight into possible deviations from that forecast. The field survey revealed no application of this or any related forecasting approach.

EXISTING APPROACHES VS. PLANNING NEEDS

Of the 9 prototypical forecasting approaches described, 7 are found to be sufficiently defined and developed to permit evaluation. As stated earlier, these evaluations apply to the capabilities of the forecasting approaches, and not to the characteristics of the forecasts which they might produce. The evaluations are necessarily of a summary nature, touching on major issues and considerations.

The previous section of this report describes a review of the planning process of the Corps of Engineers, and the role of water use forecasts in that process. The needs for improved forecasting approaches, as determined in that review, are summarized at the end of Section II. Table III-1 presents a comparison of the needs, as given in Section II, and the capabilities of various forecasting approaches, as described in Section III. Although actual forecasting techniques may differ from those shown in one or more details,

TABLE III-1. Comparison of Existing Approaches to Planning Needs

Planning Need		Single Coefficient Methods			Multiple Coefficient Methods		
	Simple Time Extrapolation	Per-Capita	Per-Customer	Unit Use Coefficient	Requirements	Demand	Contingency
Permits prediction of various measures of water use	+	+	+	+	+	+	+
Suitable for medium range forecasts	+	+	+	+	+	+	+
Suitable for long range forecasts	-	+	+	+	+	+	+
Facilitates sectoral disaggregation	-	-	+	+	+	+	n.a.
Facilitates geographic disaggregation	-	+	+	+	+	+	n.a.
Includes adequate explanatory variables	-	-	-	-	0	+	+
Requires reasonably available data	+	+	+	+	0	0	0
Provides detailed planning information	-	-	-	-	0	+	+
Demonstrated under field conditions	+	+	+	+	+	+	n.f.

Legend:
+ — Yes
0 — Unknown
- — No
n.a. — not applicable
n.f. — not found in survey

the prototypical approaches represent realistic possibilities along the continuum of all possible forecasting approaches.

Approaches Now in Use

As indicated on Table III-1 and in the preceding text, 6 of the 7 approaches have been demonstrated under Corps field planning conditions. Some approaches have enjoyed wide use and acceptance for many years; others have been applied in isolated cases, or have been adopted in the recent past. Based on information collected in the survey of planners and planning reports, summarized in Appendices A and B, the Corps' use of these 6 approaches can be contrasted to the requirements of the planning process, the use of similar methods elsewhere, and the characteristics of alternative methods.

SIMPLE TIME EXTRAPOLATION

Application by Corps Planners

Simple time extrapolation methods have been used only occasionally in Corps practice. Where water use forecasts are performed as a part of a stage 1 reconnaissance study, municipal water use is sometimes extrapolated directly from the historic record. In other cases, planners spoke of time extrapolations as providing a "first cut" estimate of industrial water use. Little or no current use appears to be made of this method.

Application by Others

The literature discloses little interest in simple time extrapolation as a water use forecasting technique. Occasionally time trends may be calculated for comparison to alternative forecasts prepared by other means (Gallagher and Robinson 1977, and Mitchell and Heighton 1977).

Comparative Advantage

The simple time extrapolation method requires the least data of any forecasting approach: necessary data consists of a historic record of aggregate water use. In every other way, however, this is the least satisfactory forecasting approach. The method is not disaggregate, it employs no explanatory variables except time, and it provides no information other than a forecast value of aggregate water use. Forecasts produced by this method would not meet the requirements of the Principles and Standards, nor would they permit evaluation of conservation practices. Even in the case of stage 1 reconnaissance studies, the per capita method is almost certainly preferable to the simple time extrapolation approach.

PER CAPITA REQUIREMENTS METHOD

Application by Corps Planners

This single coefficient method, based on service area population, is the most commonly used of all forecasting approaches. It is used to predict total water use, municipal water use, and, less frequently, sectoral water use. In project planning applications, the per capita requirements approach is normally applied at stages 2 and 3.

There are many possible variants of this approach, incorporating geographic disaggregation, various means of predicting future per capita coefficients, etc. Corps practice appears to incorporate the full range of possibilities, including some limited use of the per capita method in developing sectorally disaggregate forecasts (Baltimore, Jacksonville, and San Francisco districts, for example).

Application Elsewhere

The per capita requirements approach is discussed extensively in the literature (see for example, Hansen et al. 1979, and Tate 1977). It has a long history of application for a wide range of water use forecasting tasks. As in the case of Corps practice, many variants of the basic approach may be employed, depending upon data availability and information needs.

Comparative Advantage

The major asset of the per capita requirements method is that it assumes data which is almost universally available: aggregate water use data and population data. The approach is not convenient for sectoral disaggregation, however, and it omits consideration of all likely explanatory variables except population. In these respects, the requirements of the Principles and Standards are not met. It also fails to provide detailed information to the planning process, yielding only aggregate water use estimates based on largely implicit assumptions. The effect of future conservation measures is not easily incorporated when using this method.

On the other hand, the per capita requirements approach is well suited to the simpler needs of stage 1 reconnaissance planning, where a single, unqualified estimate of future water supply need is frequently sufficient. The simplicity of the method is consistent with the scope of a stage 1 effort, and the required data are usually readily available without detailed investigation.

PER CUSTOMER REQUIREMENTS METHOD

Application by Corps Planners

Although occasionally used by Corps planners, the per customer requirements method has never seriously challenged the per capita requirements approach in popularity. Applications are often in the context of sectorally disaggregate forecasts, where the per customer method is used to estimate industrial or commercial water use.

Application Elsewhere

Water use is generally better correlated with number of water-using customers (connections) than with population served. In spite of this fact, there is little discussion of the per customer approach in the literature (Boland 1978).

Comparative Advantage

The per customer approach is comparable to the per capita approach in most respects: data are equally available, other explanatory variables are ignored, aggregate methods are usually employed. In some cases customer counts may be more accurate than population data. Also, this method is somewhat more convenient where sectoral disaggregation is to be employed. As in the case of the per capita method, this approach is not consistent with the requirements of the Principles and Standards, or with the need to evaluate water conservation measures.

UNIT USE COEFFICIENT METHOD

Application by Corps Planners

The most common application of the unit use coefficient method has been the preparation of industrial water use forecasts as a function of number of employees. Other applications of this approach, involving commercial or other sectors of water use, appear to have been rare.

Application Elsewhere

The unit use coefficient method has been proposed for aggregate municipal water use, where the coefficient applied to per capita income (Berry and Bonem 1974). Most frequently, however, unit use coefficients apply to sectorally disaggregate water use. The method has been used for commercial water use (Wolff et al. 1966) and for industrial water use (McCuen et al. 1975). The MAIN II model uses this method for commercial, institutional, industrial, and public sectors (Hittman Associates 1969).

Comparative Advantage

Where forecasts are sectorally disaggregated, the unit use coefficient method is generally preferable to per capita or per customer methods for non-residential sectors. Data requirements are moderate, although perhaps more difficult than for per capita or per customer methods. Like other single coefficient methods, though, the unit use coefficient approach permits only one explanatory variable; all other influences on future water use are ignored.

When used in the context of a sectorally disaggregate forecast, the unit use coefficient method may represent the best means of estimating water use in sectors where multivariate requirements or demand models are not available. In this type of application, the unit use coefficient method may be consistent with the Principles and Standards. It has proven especially effective when applied at a highly disaggregate level: for example MAIN II uses this approach for each of 28 sub-sectors within the commercial and institutional sector (Hittman Associates 1969).

MULTIVARIATE REQUIREMENTS MODELS

Application by Corps Planners

The most frequent use of multivariate requirements models by Corps planners has been in the case of industrial water use. Models incorporating such factors as number of employees, recirculation ratio, productivity, etc., have been applied to subsectors within the industrial sector by Southwestern Division, Baltimore District, and others. Extension of the multivariate approach to other sectors of water use, or to aggregate municipal water use, has occurred in isolated cases (Baltimore District, for example).

Application Elsewhere

Multivariate requirements models appear frequently in the literature. These models sometimes include income among the explanatory variables, but are distinguished from demand models by the omission of water price. Multivariate requirements models have been applied to aggregate municipal water use (Burke 1970) and to water use within individual sectors such as residential (Carver 1978), commercial (Kim and McCuen 1979), and industrial (Klimek 1972). Multivariate models are sometimes developed for special purposes, such as forecasting peak period use in apartment buildings (Bobee et al. 1980). MAIN II employs multivariate requirements models for some groups of residential users, including those on flat rate schedules (Hittman Associates 1969).

Comparative Advantage

Multivariate requirements models offer much improved estimation of future water use, as a result of a more complete consideration of various trends affecting water use. They are best applied to sectoral water use, as a part of a disaggregated forecast. This approach is consistent with the requirements of the Principles and Standards and with the requirements of the planning process, including evaluation of water conservation measures.

Two disadvantages can be associated with multivariate requirements methods. When compared to demand models, requirements models can be seen to omit consideration of price as an explanatory variable, thus ignoring a possibly important factor in future water use, and increasing the requirement for model calibration in every application. Also, when compared to single coefficient methods, multivariate methods require considerably more data, including some which may be difficult to obtain.

DEMAND MODELS

Application by Corps Planners

The use of multivariate demand models, which explicitly include future water price as on the explanatory variables, has evidently been very rare within the Corps of Engineers. The survey described in this report uncovered no such application. It was learned independently, however, that the Louisville District had used the MAIN II model in preparing an alternative estimate of future water use for the Lexington Urban Study. The MAIN II model, described in Appendix C, contains demand models for some groups of residential water users. The MAIN II model was also used in the 1969-1970 period by a consultant working on various projects in the Lower Mississippi Valley Division.

Application Elsewhere

Like multivariate requirements models, demand models have been discussed in the literature and applied to water use forecasting problems comparatively frequently. Many demand models have been developed, both for aggregate municipal water use and for sectoral use (Danielson 1979, Foster and Beattie 1979, Gottlieb 1963, Grima 1972, Howe and Linaweaver 1967, Turnovsky 1969, etc). Forecasting procedures which utilize demand models have been demonstrated under many different conditions (Boland 1971, Boland et al. 1975, Carver 1978, Morris and Jones 1980, etc.).

Comparative Advantage

Demand models offer the possibility of the best obtainable estimates of future water use, provided the models are carefully developed and applied. Any factor identified as significantly affecting water use can be incorporated, including future price. Demand models can be applied to aggregate water use, but are probably best utilized for estimating sectoral water use, as a part of a disaggregated forecast. Due to the more complete specification of explanatory variables, demand models are likely to be more readily transferable from one planning situation to another, requiring less local calibration. Demand models are consistent with the requirements of the

Principles and Standards, and facilitate evaluation of water conservation measures.

By comparison to other methods, demand models require more data, including some types which may be difficult to obtain. Also, the proper application of demand models may require experience and training not always available in field planning situations. This problem is particularly acute when models must be reformulated or altered to fit local situations.

Improved Approaches

APPLICATION OF FORECASTING APPROACHES

Each of the forecasting approaches discussed in this section has been defined in a broad, non-specific way. The per capita approach, for example, is not a single technique, but represents a family of techniques sharing a common characteristic — the reliance on a per capita coefficient. Field interviews reported in Appendix B revealed the use of dozens of specific techniques, all variants of the per capita approach, in just 3 divisions and 6 districts. In the case of multiple coefficient approaches, hundreds of specific techniques could be found. This picture is further complicated by the fact that a single forecast may use techniques associated with several different approaches: the residential sector may be forecast by a per-capita technique, the commercial sector by a unit use coefficient technique, the industrial sector by a multiple coefficient requirements technique, etc.

Nevertheless, some general observations can be made, provided that the complexity of the subject matter is not forgotten. Table III-2 summarizes some of the application characteristics of the 7 forecasting approaches

TABLE III-2. Application of Forecasting Approaches

Application Characteristic	Simple Time Extrapolation	Single Coefficient Methods: Per-Capita	Per-Customer	Unit Use Coefficient	Multiple Coefficient Method: Requirements	Demand	Contingency
Facilitates forecasts consistent with Principles and Standards	no	no	no	when used in disaggregate forecasts	when used in disaggregate forecasts	when used in disaggregate forecasts	yes
Facilitates evaluation of water conservation measures	no	no	no	"	"	"	yes
Suitable for stage 1 planning applications	yes	yes	yes	yes	no, too complex	no, too complex	no, too complex
Suitable for stage 2 and 3 planning applications	no	no	no	when used in disaggregate forecasts	when used in disaggregate forecasts	when used in disaggregate forecasts	yes
Data requirements:							
quantity of data needed	very little	very little	very little	moderate	moderate to large	moderate to large	depends on application
difficulty of obtaining needed data	low	low	low	low to moderate	moderate to high	moderate to high	depends on application
Adequacy of training and experience of field planners	adequate	adequate	adequate	adequate	further training required	further training required	further training required

studied. It can be seen that consistency with the requirements of the Principles and Standards, and with the need to evaluate possible water conservation measures, is best obtained by appropriate application of unit use coefficient methods, multiple coefficient methods, and the contingency table method. There may be cases, though, where an acceptable forecast can be obtained using a per capita or per customer approach for one or more customer categories. Such cases are likely to prove the exception; normal forecasting practice will avoid these techniques.

On the other hand, the three simplest forecasting approaches, plus the unit use coefficient method, are likely to remain a part of various preliminary planning efforts, including stage 1 reconnaissance studies. The small quantities of data required, and the ease of obtaining such data, argue for their continued use in appropriate applications. It can also be seen that the training and experience of the typical field planner, while sufficient for the single coefficient methods, may require some augmentation if more complex techniques are to be adopted. Specific suggestions in this regard are offered in Section IV.

FURTHER DEVELOPMENT

The field survey disclosed a wide range of forecasting methods actually in use, including all approaches studied except the contingency table technique. Some approaches now in use are not widespread: they may have been applied in a single district, perhaps in the context of a single planning effort. Still, they have been applied, and some amount of knowledge and expertise exists somewhere within the Corps organization.

This study has indicated two areas where additional Corps planning experience would be helpful. The first is a forecasting approach, the contingency table method (Whitford, 1972), which has evidently not been used in Corps planning. This approach requires a base forecast, prepared by any of the other techniques discussed. It permits the systematic consideration of any additional factors, not explicitly considered in preparing the base forecast, which can be expected to affect future water use. In particular, the approach introduces a probabilistic dimension to water use forecasts, thus greatly increasing the amount of information which the forecast can convey to the planning process. Application of this method to the evaluation of possible future water conservation measures may be especially fruitful.

The second area for further development is the use of flexible, computerized forecasting systems. These systems would consist of an array of forecasting methods, combined with necessary data management procedures in a single computer program. The user should be able to select the proper forecasting procedure for each user category, consistent with planning needs and data availability. The forecasting system should be flexible with respect to data requirements, capable of functioning with data sets ranging from minimal to comprehensive. Where specific data are not available, computer routines can be provided to generate estimated values consistent with other data provided, or to substitute default values drawn from libraries of national or regional data. In this way, planners faced with a variety of planning needs and data availability can easily find the combination of techniques and assumptions which best fits each circumstance.

One such computerized forecasting system has been developed, and has had limited application in Corps planning. It is the MAIN II System, developed by Hittman Associates, Inc. (1969) in a research program funded by the Federal government. The MAIN II System is briefly described in Appendix C, including a summary of early application experience. A forecasting system of this type, which incorporates all of the forecasting approaches studied with the exception of the contingency table method, may provide a convenient vehicle for broadening and improving the water use forecasting capability of Corps field planners.

SECTION IV

CONCLUSIONS AND RECOMMENDATIONS

SUMMARY

Requirements for Forecasting Approaches

INTRODUCTION

Beginning in 1978, changes in federal water policy stimulated increased demands on federal agencies to improve water supply planning techniques. The Water Resources Council has substantially revised the Principles and Standards, and has implemented detailed Procedures for use in planning water resource developments. The Corps has issued guidance for the incorporation of water conservation into water supply planning. Also, there has been a significant evolution of the Corps' historic role as dam-builder. The Corps is becoming deeply involved in general water supply planning in the form of regional water supply studies, urban studies, and technical assistance activities. All of the above changes focus attention on water use forecasting procedures.

Traditional forecasting procedures, for the most part, were developed during an earlier time when the Corps' responsibility did not extend beyond the provision of water supply storage, to be sold at cost to state and local agencies. Procedures and regulations now in effect require that water use forecasts utilize methods substantially different from those used in the past. Corps planners are asked to apply new and, in some cases, untried forecasting techniques, and to collect types of data that have not been required in the past. Forecasting methods are destined to become more complex at the same time that accuracy becomes more critical. Yet, water use forecasting, as in the past, remains a relatively rare and short duration activity in the professional life of the typical field planner.

The remaining parts of this section outline the requirements for improved forecasting techniques, summarizing existing forecasting practice within the Corps, as well as the characteristics of other methods not now used by the Corps. Recommendations for improving current practice are provided, together with a proposed plan of action for achieving this result.

REQUIRED CHARACTERISTICS

Scope

Forecasting methods must permit forecasts to be made of average day water use, maximum day water use, and any measures of seasonal or peak period water use which may be required by the planning situation. While forecasts are customarily prepared for the long-run future (50 years, e.g.), the forecasting method should permit forecasts for medium-run and short-run futures as well.

Disaggregation

Both the Principles and Standards and the Corps guidance on water conservation state the need for forecasts which are disaggregated according to user category (residential, commercial, etc.). The method employed should also permit geographic disaggregation where required. In many cases, normalization for weather conditions and/or consideration of conservation measures will require separate treatment of seasonal and non-seasonal water use, or perhaps summer and winter water use.

Multi-variate Models

The Principles, Standards, and Procedures of the Water Resources Council require that all likely determinants of demand be identified and considered in the forecasting process. Past methods, which usually forecast on the basis of a single variable such as population, must be replaced with methods utilizing multi-variate models, incorporating a number of explanatory variables such as number of connections, income, price, type of housing unit, household size, industrial mix, and level of economic activity.

Alternative Futures

The Principles and Standards require consideration of a "number of reasonable alternative forecasts that would, if realized, appreciably affect plan design. . . ." Forecasting methods should facilitate the consideration of alternative futures by making all relevant assumptions explicit and by providing for convenient changes in key assumptions.

Continuity Assumptions

Most forecasting approaches rely, to a greater or lesser degree, on the assumed continuation of past trends. Reliance on such assumptions should not go beyond what is necessary and reasonable in each forecasting application and should not preclude the possibility of future changes in the relationship between water use and its explanatory variables.

Compatibility

Forecasting methods should use data which are reasonably available to field planners; the necessary expertise should be achievable under field planning conditions; and the forecasts should provide information which matches the needs of the planning process.

Existing Forecasting Practice

SUMMARY OF PRACTICE

The sterotypical water use forecast employed in Corps planning follows methods that have been in use at least 100 years. Such a forecast requires little in the way of data or planning effort. Future municipal and industrial water use is taken as the product of future population and a per capita water use coefficient. Population is obtained or interpolated from the OBERS projections for the planning area; the per capita coefficient is obtained or extrapolated from local water production records (or, in their absence from another source).

While the per capita requirements method remains standard practice, most studies reviewed include some departure from the simplest application of this method. Many studies (74 percent) estimated some or all industrial water use separately. Even after deducting industrial water use, more than half of the studies (56 percent) employed something other than an aggregate per capita coefficient for estimating municipal water use. Sometimes per capita coefficients were used, disaggregated according to geographic areas (19 percent of all studies). An even larger number of studies (28 percent) employed full sectoral disaggregation, forecasting water use separately for residential users, commercial users, industrial users, and other user groups, usually by means of per capita coefficients. Multi-variate methods were occasionally used to forecast non-industrial water use, but few details of actual techniques are available. Although most studies forecast only average day water use, some did include forecasts of maximum day water use (30 percent), seasonal water use (18 percent), and maximum month water use (5 percent).

DEFICIENCIES

1. Forecasting approaches now in use do not, for the most part, facilitate disaggregation by user sector, or by season.
2. Forecasting approaches now in use are not multi-variate approaches, as they depend primarily on population to explain future water use.
3. The consideration of alternative futures is not assisted by current methods; most underlying assumptions are implicit and may be unknown to the planner as well as to the forecast audience.
4. Current methods rely heavily on the assumption of continuity of past trends, and provide relatively little information to the planning process.
5. Although the Corps conducts much of its project planning on a multi-level, iterative basis, no established practices relating specific forecasting approaches to specific stages of planning were found. In most cases reviewed, the stage 1 effort included no water use forecast at all. Typically the water use forecast appeared for the first time at stage 2, usually in the form of a per capita requirements forecast, and was retained in stage 3.
6. There appears to be little transfer of forecasting expertise and experience among the districts, especially across division lines. Planners in one division are generally unaware of approaches adopted by others with

similar problems.

While these deficiencies describe the main stream of forecasting practice, many exceptions were found. Sectoral disaggregation was used on occasion, some methods were reported to be multi-variate in nature, and some forecasts included a number of explicit assumptions with consequent reduced reliance on continuity of past trends. No study reviewed, however, indicated full and systematic consideration of all likely determinants of demand, and none seemed particularly well suited to the consideration of alternative futures.

Other Forecasting Approaches

The literature contains descriptions of a wide range of water use forecasting approaches, ranging from single coefficient requirements methods to the use of disaggregate demand models and probabilistic techniques. Many of the simpler approaches discussed in the literature are already in use by Corps planners. Existing practice also includes some limited use of disaggregate requirements methods, perhaps employing multi-variate models. Two major categories of approaches which do not appear to have been incorporated into Corps practice are (1) disaggregate demand models and (2) probabilistic approaches, such as the contingency tree method. Both types of approaches are potentially advantageous, and have been successfully applied in other planning contexts.

DISAGGREGATE DEMAND MODELS

The use of disaggregate forecasting approaches which incorporate properly derived demand models may eliminate some of the deficiencies reported for other forecasting approaches. Econometric techniques can be used to reduce the possibility of excluding significant explanatory variables. The presence of price in the list of variables permits forecasts which consider changing water supply cost levels. Reliance upon assumptions regarding the continuity of past trends is reduced as more explanatory variables are explicitly considered, and independently projected. The greater number of explicit assumptions also facilitates the preparation of alternative forecasts corresponding to alternative futures, thereby increasing the information provided to the planning process.

These more complex approaches may have disadvantages, however. Increasing the number of explanatory variables increases the quantity and variety of data required to calibrate the demand models and to project the values of the explanatory variables. Proper use of demand models may require training and experience not now widely available among field planning personnel. Also, the high level of detail required by these methods may not be appropriate in every planning situation; simpler methods are sometimes sufficient.

CONTINGENCY TREE METHODS

Contingency tree methods are applied to base forecasts, which may be obtained by any forecasting method, including those discussed above. The purpose of the contingency tree method is to incorporate consideration of possible shifts in conditions which affect water use, but which are not explicitly considered in the base forecast. The method produces a subjective probability distribution around the base forecast value, thereby incorporating consideration of alternative futures and increasing the information provided to the planning process.

These methods rely heavily on the imagination and the judgment of the planner, who may require additional training and experience to take full advantage of their possibilities. Due to lack of application, little is known of possible data requirements.

RECOMMENDATIONS

General

1. Documentation and examples should be developed for a progression of alternative forecasting methods, ranging from the most simple approach (per capita requirements method) to relatively complex methods requiring considerable local data. Intermediate methods, that are more complex than the per capita requirements approach, would require less data than the most complex techniques.
2. Water use forecasts should be included as a part of stage 1 reconnaissance studies; in most cases, the conventional per capita requirements approach is likely to be the appropriate method.
3. Additional information should be provided to assist in the use of appropriate forecasting methods for stage 2 and stage 3 studies. Typically, the same forecasting method would be applied to both stages, with some refinement of data and assumptions occurring in stage 3.

Dissemination of Proven Methods

4. The Corps should provide for technical assistance to forecasting studies. One or more individuals with extensive experience in water use forecasting under a variety of conditions should be made available to provide informal advice and assistance to field planners. In this way, methods

successfully applied in some districts and divisions can be quickly introduced in other, similar situations.

5. In addition to the informal assistance recommended above, other means of disseminating information should be used. Wherever forecasting methods which appear to represent an improvement over past practice are successfully applied by Corps planners, the planning reports describing those applications should be made generally available to other Corps planners who might face similar problems.

6. In addition to the steps proposed in recommendations 4 and 5, training sessions for field planners should include practice-oriented workshops where participants can gain hands-on experience in the use of improved forecasting methods. These workshops should be as realistic as possible so as to increase both the knowledge and confidence of the participants.

Field Tests of Existing, Unproven Methods

7. A comprehensive, flexible, computer-based forecasting approach, such as the MAIN II system (see Appendix C), should be field tested and evaluated. This forecasting system can be used, within limits, with as much or as little data as may be available: missing values are generated internally or supplied from libraries of national averages. The field tests should include trials with varying amounts of locally supplied data.

8. A probabilistic forecasting approach, like that proposed by Whitford (1972), should be field tested and evaluated. A wide range of alternative futures should be considered, so that the data requirements can be assessed.

9. The results of the field trials proposed in the previous recommendations, if satisfactory, should be fully disseminated to field planners by the methods described in recommendations 4, 5, and 6.

New Methods

10. Based on the results of field trials proposed in recommendations 7 and 8, the Corps should consider the support of a comprehensive, flexible forecasting system which is capable of functioning under a wide range of data availability, and which produces disaggregate forecasts, possibly expressed in probabilistic terms. This forecasting system could be based on further elaboration of the MAIN II System, or experience with the MAIN II System may suggest a departure from this format. Generally the forecasting system should permit district and division planners with limited forecasting experience to make effective use of available local data, and to select the most appropriate forecasting technique for each situation.

PROPOSED PLAN OF ACTION

Phase I-Immediate Action

1. Arrangements should be made to provide field planners with access to informal advice and technical assistance on water use forecasting matters (recommendation 4).
2. As proposed in recommendations 7 and 8, a field trial of forecasting techniques should be initiated. Several different planning areas may be used, but a range of approaches should be attempted in each area. If the

MAIN II system is used, for example, it may be applied once with only the minimum data supplied, again with an intermediate quantity of data supplied, and again with complete data. The forecast or forecasts provided by the MAIN II system can be used as base forecasts for a contingency tree analysis. All field trials should be performed within the context of actual planning efforts, and with the assistance, and under the immediate direction of the responsible field planners.

Phase II

3. Procedures should be implemented for continuing review of forecasting studies performed in the field, with dissemination of noteworthy results to other field planners (recommendation 5).
4. As the field trials are completed, the results should be evaluated and disseminated as appropriate (recommendation 9).

Phase III

5. Based on the experience of providing technical assistance to field planners and on the results of the field trials, final written guidance for water use forecasting should be prepared and disseminated. The guidance should present a comprehensive system of forecasting approaches, designed to provide useful and reliable forecasts under a wide range of planning conditions and data availability. These approaches will combine the best of present practice with the methods (or modifications of those methods) which were used successfully in the field trials. The adoption and continuing maintenance of this guidance implements recommendations 1, 2, 3, and 10.

6. A series of practice-oriented workshops should be conducted, designed to familiarize field planners with application of the written guidance pertaining to water use forecasting and to develop proficiency in the use of the forecasting techniques described in that guidance (recommendation 6).

APPENDICES

APPENDIX A

RESULTS OF MAIL SURVEY OF CORPS DISTRICTS/DIVISION

Description of Survey

A mail survey of Corps field planners was undertaken in order to determine

1. the role of water use forecasts in planning;
2. the characteristics of methods presently used; and
3. the perceived needs for improved forecasting methods.

A selected representative in each of 11 divisions and 35 districts was sent a two-page questionnaire requesting information about water use forecasts performed within the past five years. A copy of the questionnaire and of its cover sheet are shown as Figure A-1. A memorandum explaining the purpose of the study, signed by James R. Hanchey, Acting Director, Institute for Water Resources, was sent to the attention of each of the Division and District Engineers.

Of the 46 divisions and districts covered by the mail survey, 36 responded with a completed questionnaire. Copies of project reports were provided in many cases. In addition, water use forecasting practices in 3 divisions and 6 districts were reviewed by means of personal interviews; this phase of the work is described in Appendix B. In some cases, responses of several districts were consolidated in a single reply. Only 2 divisions and 4 districts failed to provide any information (see Table A-1).

The mail survey was designed to obtain specific information about recent water use forecasts. The major questions asked include:

PLANNING AND MANAGEMENT CONSULTANTS LTD.
P.O. BOX 927
CARBONDALE, ILLINOIS 62901

November 14, 1980

The following questions refer to the use of forecasts of municipal and industrial water use in planning. Forecasts may be used in planning projects which include a water supply purpose, in urban studies, or in river basin studies. Your response, along with others, will assist us in determining the role of water use forecasting in Corps planning, as well as the need, if any, for improved guidance and procedures.

We will be very appreciative if you would complete the enclosed questionnaire and mail it to us in the self-addressed, stamped envelope by November 26, 1980. Thank you for your cooperation.

IF YOU HAVE ANY QUESTIONS, PLEASE CALL JOHN BOLAND

AT (301) 338-7103 BETWEEN 9:00 A.M. AND 4:00 P.M., EST

Figure A-1. Mail Questionnaire as Sent to Corps Divisions/Districts

QUESTIONS	ANSWERS			
	Study No. 1	Study No. 2	Study No. 3	Study No. 4
1. What recent studies (last 5 years) in your district included municipal and industrial water use forecasts? (Please name only one study for each box.)				
2. For each study, who performed the water use forecasts? (Please check)	Corps Personnel ___ Consultant to Corps ___ Local Gov't ___ Planning Agency ___ Water Utility ___ Other: ___	Corps Personnel ___ Consultant to Corps ___ Local Gov't ___ Planning Agency ___ Water Utility ___ Other: ___	Corps Personnel ___ Consultant to Corps ___ Local Gov't ___ Planning Agency ___ Water Utility ___ Other: ___	Corps Personnel ___ Consultant to Corps ___ Local Gov't ___ Planning Agency ___ Water Utility ___ Other: ___
3. For each study, what was the forecast period? Please identify the <u>base year</u> and the <u>last year</u>.	Base year ___ Last year ___	Base year ___ Last year ___	Base year ___ Last year ___	Base year ___ Last year ___
4. What was the forecast unit or units? (Please check)	Annual water use ___ Average day water use ___ Maximum day water use ___ Seasonal water use ___ Maximum month water use ___ Other: ___	Annual water use ___ Average day water use ___ Maximum day water use ___ Seasonal water use ___ Maximum month water use ___ Other: ___	Annual water use ___ Average day water use ___ Maximum day water use ___ Seasonal water use ___ Maximum month water use ___ Other: ___	Annual water use ___ Average day water use ___ Maximum day water use ___ Seasonal water use ___ Maximum month water use ___ Other: ___
5. What types of water use were forecasted? (Please check)	Total water use ___ Municipal water use ___ Industrial water use ___ Residential water use ___ Commercial water use ___ Institutional water use ___ Public/unaccounted water use ___	Total water use ___ Municipal water use ___ Industrial water use ___ Residential water use ___ Commercial water use ___ Institutional water use ___ Public/unaccounted water use ___	Total water use ___ Municipal water use ___ Industrial water use ___ Residential water use ___ Commercial water use ___ Institutional water use ___ Public/unaccounted water use ___	Total water use ___ Municipal water use ___ Industrial water use ___ Residential water use ___ Commercial water use ___ Institutional water use ___ Public/unaccounted water use ___
6. What method was used to make the forecast? A. MUNICIPAL (Please check)	Population times per capita use ___ Population times per capita use by user class ___ Population times per capita use by geographical region ___ Other: ___ (Briefly describe on a separate sheet)	Population times per capita use ___ Population times per capita use by user class ___ Population times per capita use by geographical region ___ Other: ___ (Briefly describe on a separate sheet)	Population times per capita use ___ Population times per capita use by user class ___ Population times per capita use by geographical region ___ Other: ___ (Briefly describe on a separate sheet)	Population times per capita use ___ Population times per capita use by user class ___ Population times per capita use by geographical region ___ Other: ___ (Briefly describe on a separate sheet)
B_1 INDUSTRIAL (Please check)	Per employee use rate ___ Per capita population use rate ___ Per employee use rate plus other variables ___ Other: ___ (Briefly describe on a separate sheet)	Per employee use rate ___ Per capita population use rate ___ Per employee use rate plus other variables ___ Other: ___ (Briefly describe on a separate sheet)	Per employee use rate ___ Per capita population use rate ___ Per employee use rate plus other variables ___ Other: ___ (Briefly describe on a separate sheet)	Per employee use rate ___ Per capita population use rate ___ Per employee use rate plus other variables ___ Other: ___ (Briefly describe on a separate sheet)
B_2 If industrial water use was separately forecast, were the calculations made for:	Water use of specific firms ___ Water use of groups of firms ___ (Separate calculations were not made) ___	Water use of specific firms ___ Water use of groups of firms ___ (Separate calculations were not made) ___	Water use of specific firms ___ Water use of groups of firms ___ (Separate calculations were not made) ___	Water use of specific firms ___ Water use of groups of firms ___ (Separate calculations were not made) ___

PLEASE TURN SHEET OVER

Figure A-1. (cont.). Mail Questionnaire as Sent to Corps Divisions/Districts

7. Based on past experience with these water use forecasts, what have been the most important problems and/or deficiencies?

8. In view of the recent Water Resources Council guidance concerning the projection of future water requirements (which is also included in the Corps' detailed Procedures Manual on the Evaluation of Water Conservation for Municipal and Industrial Water Supply), please identify any new problems and/or deficiencies.

9. Under separate cover, please send copies of any of the available planning reports or studies that include water use forecasts which were mentioned in Question 1.

THANK YOU FOR YOUR THOUGHTFUL CONSIDERATION TO THE ABOVE QUESTIONS

Figure A-1. (cont.). Mail Questionnaire as Sent to Corps Divisions/Districts

TABLE A-1. Source of Information on Forecasting Practices

	Response to Questionnaire	Personal Interview	No Response
DIVISIONS			
Lower Mississippi Valley	X		
Missouri River	X		
New England	X		
North Atlantic		X	
North Central			X
North Pacific			X
Ohio River	X		
Pacific Ocean	X		
South Atlantic		X	
South Pacific	X		
Southwestern	X	X	
DISTRICTS			
Memphis	X		
New Orleans	X		
St. Louis		X	
Vicksburg	X		
Kansas City	X		
Omaha	X		
Baltimore		X	
New York	X		
Norfolk	X	X	
Philadelphia			X
Buffalo	X		
Chicago	X		
Detroit	X		
Rock Island			X
St. Paul	X		
Alaska	X		
Portland	X		
Seattle	X		
Walla Walla	X		
Huntington			X
Louisville	X		
Nashville			X
Pittsburgh	X		
Charleston	X		
Jacksonville	X	X	
Mobile	X		
Savannah	X	X	
Wilmington	X		
Los Angeles	X		
Sacramento	X		
San Francisco	X	X	
Fort Worth	X		
Galveston	X		
Little Rock	X		
Tulsa	X		

1. Who performed the forecast?
2. What was the forecast period?
3. What measures of water use were forecast?
4. What types of classifications of water use were forecast?
5. What forecasting method(s) were used?
6. What have been the most important forecasting problems?
7. What problems are foreseen in implementing new guidance pertaining to water use forecasting?

Results of Survey

The following paragraphs describe the results of the mail survey, based on 29 responses covering 36 divisions and districts. In addition, copies of 20 studies were received from individuals who completed mailed questionnaires, and copies of 7 additional studies received from individuals who were personally interviewed (see Appendix B).

QUESTIONNAIRE

Frequency of Water Use Forecasts

The 29 responses reported a total of 58 studies performed in the last five years which included forecasts of municipal and industrial water use.

Organization Performing Forecast

Questionnaire responses, tabulated on Table A-2, indicate that most water use forecasts are performed by Corps personnel (33 percent of responses) or by consultants employed by the Corps (33 percent of responses). The use of

TABLE A-2

Authorship of Water Use Forecasts
(Question 2)

	Corps Personnel		Consultant to Corps		Local Government		Planning Agency		Water Utility		Other		Total Percentage
Forecasts done exclusively by:	19/57	(33%)	19/57	(33%)			1/57	(2%)	1/57	(2%)	3/57	(5%)	75
By Corps Personnel and			1/57	(2%)	1/57	(2%)	2/57	(3%)			1/57	(2%)	9
By Corps Personnel, Consultant to Corps and					1/57	(2%)	1/57	(2%)					4
By Corps Personnel, Consultant to Corps, Local Gov't, Utility and											1/57	(2%)	2
By Consultant to Corps and							1/57	(2%)					2
By Local Gov't and							3/54	(5%)					5
By Local Gov't Planning Agency Water Utility and											2/57	(3%)	3
													100

Comments: 1. Total number of studies included in 29 questionnaires is 58.
2. The author of 1 of the studies has not been indicated.

forecasts prepared exclusively by local agencies was reported for only 17 percent of the studies.

It was not possible to determine the extent to which forecasts attributed to the Corps or its consultants are based on prior forecasts by local planning agencies. In some cases, especially where no suitable local forecasts are available, the Corps may undertake the entire task. In others, existing local forecasts may be subjected to relatively minor modification by Corps personnel or Corps consultants (revision of population forecasts to be consistent with OBERS projections, for example). The forecasts attributed to the Corps in the survey responses appear to include examples of both procedures.

Forecast Period

Most studies employed a forecast period of 50 years: of the 44 studies for which this information was provided, 72 percent used forecast periods of 50 to 55 years. The shortest forecast period reported was 15 years; the longest was 100 years.

Measures of Water Use Forecast

Average annual (average day) water use was the most commonly used unit of measurement, appearing in 89 percent of reported studies (Table A-3). Maximum day water use was forecast in 30 percent of the reported studies; seasonal water use was considered in 10 studies (18 percent). Only 3 studies (5 percent) reported analyzing maximum month water use.

TABLE A-3

Forecast Units Used in Studies
(Question 4)

	Average Day Water Use (Incl. Annual)	Maximum Day Water Use	Seasonal Water Use	Maximum Month Water Use	Other	Total Percentage
Units used exclusively:	33/57 (58%)	5/57 (9%)	1/57 (2%)			69
Average day use and		8/57 (13%)	5/57 (9%)	1/57 (2%)		24
Average day, maximum day and			2/57 (3%)			3
Average day, maximum day, seasonal, and				1/57 (2%)		2
Average day, maximum day, maximum month, seasonal, and					1/57 (2%)	2
						100

Comments:
1. Total number of studies included in 29 questionnaires is 58.
2. The forecast unit used in 1 study has not been indicated.

Classes of Water Use Forecast

Respondents indicated at least some disaggregation of total water use for many of the reported studies (Table A-4). In nearly 74 percent (42) of the reported studies, industrial water use was separately forecast; 47 percent (27) of the studies forecast residential water use; and commercial water use was considered in 42 percent (24) of the studies. Institutional water use and public/unaccounted water use were forecast in 25 and 33 percent of the studies, respectively.

Forecast Method

Municipal water use. In all but seven cases, municipal water use was forecast on a per-capita requirements basis (Table A-5). Of those studies using this approach, the per capita calculation was performed separately for user classes in 17 studies (30 percent) and for geographical areas in 11 studies (19 percent).

Industrial water use. Industrial water use was estimated by means of a per capita requirements coefficient in 5 studies, by a per employee use rate in 7 studies, by a per employee use rate in conjunction with other variables (such as recirculation ratio, gross product, etc.) in 21 studies (Table A-6). Respondents indicated that 15 studies used none of the above methods for industrial water use. A total of 50 studies incorporated separate forecasts of industrial water use, and 16 (32 percent) of these calculated water use for specific firms, rather than aggregate industrial water use (Table A-7).

Important Problems

The verbatim responses to question no. 7, pertaining to important

TABLE A-4

Types of Water Uses Forecasted
(Question 5)

	No Aggregate Forecast Reported	Disaggregate Forecast(s) Plus Municipal Use	Disaggregate Forecast(s) Plus Total Use	Disaggregate Forecast(s) Plus Municipal and Total Use	Total Percentage
No Disaggregate Forecast			13/57(24%)		24
Industrial		4/57(7%)		8/57(14%)	21
Public/Unaccounted		1/57(2%)	1/57(2%)		3
Industrial and Residential				2/57(3%)	3
Industrial and Institutional				2/57(3%)	3
Industrial and Public/ Unaccounted				1/57(2%)	2
Industrial, Residential, and Commercial	3/57(5%)	2/57(3%)		3/57(5%)	14
Industrial, Residential, and Public/Unaccounted				1/57(2%)	2
Industrial, Residential, Commercial and Institutional		1/57(2%)		1/57(2%)	3
Industrial, Residential, Commercial and Public/Unaccounted			1/57(2%)	3/57(5%)	7
Industrial, Residential, Commercial, Institutional, and Public/Unaccounted		2/57(3%)	1/57(2%)	7/57(12%)	18
					100

TABLE A-5

Methods Used to Make Municipal Water Use Forecasts
(Question 6A)

	Population Times Per Capita Use	Population Times Per Capita Use Per User Class	Population Times Per Capita Use By Geographical Region	Other	Total Percentage
Methods used exclusively:	25/57 (44%)	11/57 (20%)	7/57 (12%)	7/57 (12%)	88
Population times per capita use and		3/57 (5%)	1/57 (2%)		7
Population times per capita use by user class and			1/57 (2%)		2
Population times per capita use, population times per capita use by user class, and			2/57 (3%)		3
					100

Comments: 1. Total number of studies in 29 questionnaires is 58.
2. Method used to make municipal water use forecast in 1 study has not been indicated.

TABLE A-6

Types of Water Use Coefficients Applied to Make Industrial Water Use Forecasts (Question $6B_1$)

	Per Employee Use Rate	Per Capita Population Use Rate	Per Employee Use Rate Plus Other Variables	Other	Total Percentage
Types of coefficients used exclusively	6/47 (13%)	4/47 (9%)	16/47 (34%)	15/47 (32%)	88
Per employee use rate; and			3/47 (6%)		6
Per employee use rate plus other variables, and				2/47 (4%)	4
Per capita population use rate, and				1/47 (2%)	2
					100

Comments: 1. Total number of studies included in 29 questionnaires is 58.
2. The question No. $6B_1$ was left blank for 11 studies.

TABLE A-7

The Levels of Disaggregation in Separately Forecasted Industrial Water Uses (Question $6B_2$)

	Water Use of Specific Firms	Water Use of Groups of Firms	Separate Calculations Not Made	Total Percentage
Each category exclusively	9/50 (18%)	28/50 (56%)	6/50 (12%)	86
Water use of specific firms, and		7/50 (14%)		14
				100

Comments: 1. Total number of studies included in 29 questionnaires is 58.
2. The level of disaggregation for 8 studies has not been indicated.

problems and/or deficiencies found with past water use forecasts, are listed below.

"Based on past experience with these water use forecasts, what have been the most important problems and/or deficiencies?"

1. Most important to the accuracy of forecasts is the estimate of recirculation ratios for various industry and the reasonableness of the particular area to achieve the ratios. Similarly, the estimate of future per capita uses is important to the accuracy of forecasts. Numbers of people and numbers of employees are sometimes disputed, but WRC requirements to use BEA projections settles the argument when Federal funds or project recommendations are involved.

2. (a) Many water supply agencies, particularly the smaller ones, do not maintain records of water use by sector and season.

   (b) Most small water supply agencies do not plan for future needs beyond 5 years into the future.

   (c) In a regional study encompassing many agencies (over 100 in both studies listed), it is very expensive and time-consuming to gather data.

   (d) Water supply agency boundaries do not conform to census tracts, O-D zones, or other geo-political boundaries. This makes forecasting more difficult.

3. Study No. 1 involved two States whose agencies responsible for compiling water resources data and making projections foresee different futures (e.g., large increases in irrigation demand versus no change in irrigation) and use different forecasting techniques (e.g., using industrial indices versus per capita projections). Furthermore, it is near impossible to predict major breakthroughs in processing techniques, new regulations (who, 50 years ago, would have predicted today's environmental cleanup regulations), and the introduction of new industries (who could have imagined the growing significance of soybeans and sunflowers to the Red River of the North basin's agricultural and processing economies).

4. Inadequate data available.

5. POD has very little experience with water use forecasts. In the case of Guam, better data availability for more in-depth study could have produced more reliable forecasts. In the case of American Samoa, the most important deficiencies have been related to the lack of adequate data. The study on the water demand estimating model was done as a part of the Kaneohe Bay Water Resources Study. It has not been used to make any forecasts.

6. For basin studies, municipal per capita use rates may vary considerably from area to area depending on municipal water use (actual) and population served data. It is difficult sometimes to obtain base condition sector data, such as outdoor watering, commercial, and public services use data. Some large commercial user and public supplied industry water users may affect the per capita use rates. Separation of public-supplied industry from self-supplied industry water users may require considerable survey work. Some studies project industry use based on current industry use in the study area and may omit future industry use for some SIC's as projected by OBERS.

7. Only the Metro Denver study has been completed. The projections were not used in formulating recommendations. The projected demands and related supply data were provided to State and local interests as a basis for regional policy judgments. No problems or deficiencies were identified.

   The water supply element of the Metro Sioux City study was limited to rural areas and small towns. The methodology included a conservation study. No significant problems or deficiencies have been identified. A tendency to overproject unaccounted for losses was recognized and corrected.

   The reconnaissance reports for the Eastern and Western Dakotas studies were completed in FY 1980. The population data were considered somewhat questionable at the end of the census period. 1980 census data will be used as a basis for refined projections in Stage 2, which will also include conservation studies.

8. Projections for Industrial Use made with empirical relationships often do not reflect the views and long range plans of affected industries. Affected industries should be contracted to obtain information on what they feel their water use will be during the projection period. This information should be used to make adjustments in the industrial use projections made with empirical relationships.

9. The problems have always been obtaining accurate water use data by sector (residential, commercial, industrial, etc.) from the water utilities.

10. We report on only this one report: There were no apparent deficiencies, but I must add that it was not subject to really critical review.

11. The limited amount of data that are readily available beyond total water use and population; and the extensive amount of manpower required to obtain additional. There appears to be little if any data to explain why gross per capita use has historically shown an increasing trend, why unit use for a class of user varies from one

geographical area to another, or why different cities in the same metro area will have different use rates.

12. Convincing the public of the conclusions. In particular this is a problem with a study which requires a solution to be implemented.

13. Lack of historical data has been a problem. Many municipalities do not maintain type of records to give the breakdowns needed. Industries are often reluctant to give information on water use or plans for expansion. Personnel working with municipal water supply systems have indicated that metered readings are subject to considerable error — particularly for large users.

14. Our effort has been primarily in development of a two dimensional model which reacts in the same way as our aquifer does to historical pumpage. This has been completed but the expertise required to operate and maintain the model locally is not available. In order to solve this dilemma, this district has contracted study efforts in this area to the U.S. Department of the Interior, Geological Survey in Nashville. A copy of the proposed report outline is attached. Completion date is June 1981.

15. (a) Obtain accurate disaggregated base data.

    (b) Lack of local indicators on which to project base data.

16. Significant problems were associated with delineating service areas, disaggregating population within each area, coordinating these tasks with the States.

17. Choosing an appropriate population forecast methodology for use in planning as this has a major impact on the range of alternatives available to meet water supply needs.

    How severe a drought condition should be used as basis for developing alternatives or design?

    Should the potential for demand reductions through nonstructural measures (e.g., water conservation) be included or excluded from planning and design considerations?

    Should the per capita water use rate be at a constant value rate or increasing (decreasing) with time?

    In the first stage of study at Campground Lake, available forecast information was obtained from a variety of sources. Future studies would require forecasting for large periods of time, say to the year 2030. Conflict may occur as result of a local water company's forecasting information not agreeing with Corps projections.

18. This project has not been funded for construction; therefore, no forecasting problems have become apparent. A followup study would

be necessary to assess growth and use projections under present (without project) conditions to identify potential problems in the forecasting methodology.

The prior practice of extrapolating the general historic national trend of increasing per capita consumption was questioned and discarded. Analysis of water-use data for Portland revealed a leveling off or a decrease in per capita consumption over the past several years. Similar trends have been observed in Seattle, Washington. Limited growth in consumption was assumed in the Metro Study.

19. (1) Are population projections correct?
    (2) Are per capita use rates correct?
    (3) Wide variations in water uses on per capita or per employee use bases can be expected in a large study area. Domestic uses seem to vary with income class. Per employee industrial uses vary widely for industries within common S.I.C. groups.

20. Growth rate is usually less than projected (forecasted). This is based on experience of our contractor, as we have only done one study.

21. The most significant issue is the amount of data needed to develop projections in the appropriate level of detail and the need to develop projections 30-40 years into the future.

22. Past difficulties with water use forecasts were centered on the following issues:
    (1) Choosing an appropriate population forecast methodology for projecting future demands. There is a wide variance, sometimes, between OBERS, state, and local planning agency projections.
    (2) Should per capita water use rates remain constant over the projection period or should these rates reflect conservation measures and other factors which may have an impact over time?
    (3) What drought severity conditions should be used to determine available water supplies?

23. The relatively insignificant nature of water supply in this study deemed it unnecessary to evaluate deficiencies, problems, etc. in the methodology employed.

24. (a) Uncertainty of population estimates and forecasts.
    (b) Poor records and unavailable data concerning historical demand.

25. Disagreement on population forecasts.

26. (a) Basic data are usually unavailable - accurate historical water use data including disaggregations; accurate population projections.
    (b) Forecasts do not distinguish among water uses.

(c) Forecasts do not account for changing per capita use over time-what factors or variables influence water use and how these factors change over time.
(d) Effects of recent droughts in California raise doubts about veracity of past per capita use values, calculations and projections.
(e) Expertise in water use forecasting is lacking.

Three questionnaires contained no response to this question.

Anticipated Problems

The verbatim responses to question no. 8, regarding anticipated problems and/or deficiencies, follow.

"In view of the recent Water Resources Council guidance concerning the projection on future water requirements (which is also included in the Corps' detailed Procedures Manual on the Evaluation of Water Conservation for Municipal and Industrial Water Supply), please identify any new problems and/or deficiencies."

1. The issue of conservation has always been involved with establishing the recirculation ratios and per capita use rates. I don't see any changes just because the council decides to make explicit what was once implicit in the estimating of future requirements. The reasonableness of an area to achieve conservation is more at issue.

2. In Study No. 1, water conservation was presented in what we felt was reasonable detail. Specific conservation measures were translated from water savings into cost reductions for treatment plant construction and operation. And a drought emergency plan was developed using contingent conservation measures on top of long-term measures. But quantification of contributions to the NED and EQ objectives, etc., as proposed in the "Procedures Manual" was not attempted. Nor do we feel that implementation of all the "Procedures Manual" elements is warranted or needed. We fear that the outcome would be highly structured and regulation-bound water conservation planning process that would hamper rather than enhance our capability for providing a meaningful planning service to communities. Witness the debilitated state of our flood control planning efforts — large expenditures of manpower, time, and money, but less and less output that is implementable or useful to local interests.

   Within reason, some quantification makes sense. In retrospect, for instance, we should have estimated the costs of water saving devices, promotional campaigns, etc., to see whether projected savings offset these costs. Perhaps we could have been somewhat more comprehensive in the discussion of qualitative impacts on environment, lifestyles, etc. By doing so, we could give communities and individuals the tools to make an informed choice whether or not to adopt any of the proposed conservation measures.

Note that integration of conservation measures still is a local decision — one involving individual homeowner and businessman cooperation as much as that of local units of government. Therefore, prospects are dim for an accurate assessment of public acceptance of a proposed long-term conservation program. The "Procedures Manual" admits that at best the goal is not to reach a definitive yes or no decision regarding social acceptance, but to improve judgment as to the probable response of various sectors of the community.

With the uncertainties of public acceptance compounded by the unreliabilities of long-term projections, we would be stretching our prognostic credibility and most likely wasting time, effort, and money to carry the analysis to the n^{th} degree as proposed in the "Procedures Manual." The "Procedures Manual" would extend our convoluted planning process into another area of possible Corps public service and, rather than clarifying choices and impacts, probably would generate a fog of rhetoric that would smother the alternatives and findings.

3. New problems and deficiencies would be related to the adequacy of available data and the cost of obtaining new data necessary for following the Corps' Procedures Manual. Full compliance with these procedures would be significantly more costly and more time-consuming.

4. Water rates may support other governmental functions, such as ambulance service, and it may be difficult to discuss the true cost of water. Availability of other types of data may result in limitations of the study.

5. We do not yet have experience in *applying* the procedures contained in the manual, but offer this speculation: In some parts of western South Dakota where inadequate quality is often a greater problem than inadequate quantity, conservation of existing supplies may be totally irrelevant. The need is more for planning to make efficient use of potential imported supplies. Where usage rates are low because the water tastes awful and stains the laundry, the acquisition of good water would naturally be accompanied by increased usage. Perhaps there should be explicit recognition that some contexts deserve "modified procedures."

6. Public and water supply institutions acceptance of water conservation measures is envisioned as the most difficult problem in implementing water conservation measures. In the past, solutions to water supply problems were to more often find additional water

supply sources rather than to conserve existing water supply sources for future use.

7. Same problem still exists because many of the water utilities are not metered or only partially metered.

8. No difficulties seen. The new requirements will simply mean that a bit more data will have to be obtained and displayed (as for maximum seasonal..maximum daily..consumption, etc.).

9. Coding water meters (billing records) so that disaggregated data can be obtained is likely to be costly and time consuming, it is not clear how the coding will be accomplished or who will assume the cost. Could add significantly to study time. There is little meaningful data on the effectiveness of conservation measures. If water use can be correlated to specific parameters such as income, lot size, etc. the data is not available for projecting those impacts into the future.

10. None, really, other than more time, money and effort in the study phase.

11. As discussed in 7 above, the data base to give breakdowns necessary for conservation analysis is often lacking. Analysis of conservation measures for industrial users is very difficult due to many types of industries and processes.

12. (a) As long as water supply is a local responsibility, provision for such water in a Federal project must satisfy a locally perceived need in a timely manner, and the alternative must clearly be to the economic advantage of the locals. The guidelines impede both of these essentials.

(b) An attempt to identify and make a distinction between areas receiving direct benefits and/or costs, and areas in which external economies and/or diseconomies are generated within a water supply service area, are impractical. The distinctions would be difficult to evaluate for present conditions, and the application of such principles to long-range projections appears to have no merit.

(c) Consideration of seasonal variations in water supply demand when sizing a water supply source based on long-term predictions appears totally unnecessary.

(d) Speculation about future institutional arrangements as a determinant of water supply needs will, in most cases, be simple conjecture on the part of the evaluator. Also, the evaluator will undoubtedly be completely outside of the arena in which institutional decisions are made.

(e) The division of domestic and commercial will present a problem since separate metering is not normal and most municipal records do not include a disaggregate of these components. A further breakdown of the residential, commercial, and industrial sectors, which the guidelines may be implying, would appear unreasonable, especially when applied to long-range predictions.

13. Overcoming differing water supply needs projections made by other public and private water utilities.

14. The Days Creek General Design Memorandum was formulated under prior planning criteria, and is not strictly applicable in this case. Problems are foreseen in the area of related factor analysis, where the types of data outlined in this category are either not available, or can be obtained only at considerable time and cost.

15. The concept of conservation is not uniformly accepted at local levels responsible for implementation. This leads to difficulties in reaching agreement on future water requirements. Local governments (counties, municipalities, special) improved management and conservation of local water supplies require cooperative agreements among these entities. Securing such agreements prior to, or as elements of, regional water supply plans are essential to achieve plan implementability. Local social attitudes and acceptance of new concepts are critical factors in improved water supply management planning.

16. The required level of detail is excessive. The attempt to measure the likelihood of numbers being estimated 30-40 years in the future is probably unwise and the need to incrementally justify conservation measures will impose data collection requirements that are beyond what is reasonably prudent.

17. Our limited experience to date has not revealed any new problems or deficiencies with the new guidance concerning projection of future water requirements.

18. It appears that water conservation will only postpone the need for development of additional water supply, not eliminate the need.

19. No staff expertise available within District Office to conduct adequate review of demand forecasts submitted by local governments.

    Lack of staff may reduce effective monitoring of forecasts and use of Conservation Procedures Manual.

20. (a) Use of average yield rather than firm yield may produce misleading results - average yield may substantially overestimate available supply; firm yield reveals absolute limits of supply and when rationing or additional supply (conservation or new source) so policy makers understand relationship between population growth and water supply limits or rationing.

(b) Training courses are needed as are guidelines in selecting the "best" M and I growth forecast.

(c) Since agriculture is a dominant water user, this sector should not be ignored in examining tradeoffs between agricultural and M and I water uses.

(d) The level of disaggregate forecasting does not seem to produce significantly better results; quantitative forecasting compliance is often beyond District capabilities especially when basic data are lacking.

Nine respondents either failed to answer this question, stated that no problems were anticipated as yet, or repeated their answer to question no. 7, sometimes adding "only more so."

Study Reports

The 20 study reports received, as well as 7 additional reports obtained in conjunction with personal interviews, were subjected to limited further analysis. This analysis was intended to provide further details on the forecasting methods employed. Results are summarized as Table A-8, and discussed briefly in the following paragraphs.

All but 1 study stated that per capita use rates were derived from historic data. In 78 percent of the studies, the per capita use rate was assumed to vary over the period of the forecast (usually increasing). Of those studies which employed per employee use coefficients to estimate industrial water use, 8 based the use rate on historic data, and 4 of those permitted the use rate to change over time. Historic water use data were obtained from water production records in 44 percent of the studies, from water billing (meter) records in 22 percent of the studies, and the source was not stated in the remainder.

TABLE A-8. Summary of Analysis of Study Reports*

	No. of Studies
1. Per capita use coefficients	
a. Based on historical water use in planning area	24
b. Assumed to change over forecast period	21
2. Per employee use coefficients	
a. Based on historical water use in planning area	9
b. Assumed to change over forecast period	5
3. Source of historical water use data	
a. Water production records	12
b. Water billing records	6
c. Unknown	9

4. Other methods of forecasting industrial water use

a. Based on projections of changes in manufacturing processes, processing efficiencies, new industries, etc.

b. Industrial water use projections obtained from firms themselves.

c. Judgement method, incorporating knowledge of water use in individual plants, changes in patterns of industrial growth, and assumptions regarding future growth patterns.

d. Incorporates consideration of relative productivity.

e. Based on manufacturing earnings.

f. Based on physical output.

h. Forecast as a percentage of total water use.

i. Extrapolation of historic industrial water use.

*Based on analysis of 27 reports.

In addition to the several general methods for forecasting industrial water use listed on the questionnaire, 16 of the 27 studies analyzed here indicated that other techniques had been used. The reported techniques have been summarized as nine distinct approaches, ranging from estimating industrial water use as a fixed percentage of the total to relatively complex projections of technology, productivity, industrial growth, etc.

APPENDIX B

FORECASTING PRACTICES OF SELECTED DISTRICTS/DIVISIONS

Description of Survey

The mail survey described in Appendix A was complemented by a series of personal interviews with selected personnel at three divisions and six districts. The interviews were conducted, on behalf of the contractor, by Dr. John J. Boland between November 1980 and February 1981. The divisions and districts were selected by members of the OCE Water Conservation Task Force, in conjunction with the contractor and IWR. Each interview followed the same general outline, with the exception of the Norfolk District. In the latter case, forecasting techniques employed in a single, current study were explored in detail. Other interviews attempted to survey forecasting practice generally, as it has developed in the subject district or division. The results of the interviews are described in the following sections.

North Atlantic Division

ROLE OF WATER USE FORECASTS

The Division staff does not perform water use forecasts, but serves a review and training function for the districts. The districts prepare and use forecasts for a wide range of purposes (see Baltimore and Norfolk Districts). The following comments summarize the experience of the Division staff as it has reviewed district studies during recent years.

CORPS-PREPARED FORECASTS

Forecast Type and Duration

Most forecasts are prepared in connection with multi-purpose projects and are for a forecast period of 50 years. Usually only average day water use is projected. In the last few years, however, forecasts have begun to appear for many other kinds of studies, and forecast periods as well as the water use measures being forecast have become more diverse (see Baltimore District).

Forecast Methods

The most common forecast method employs a single per capita coefficient to estimate the sum of municipal and industrial water use. The coefficient is usually obtained by extrapolating the historic record. More recently, however, sectoral and geographic disaggregations have been employed, industrial water use is more likely to be forecast by some other means (such as on a per employee basis), and other explanatory variables have been introduced.

Data Sources

Population, employment, and other socioeconomic data and projections are obtained from the U.S. Bureau of the Census, OBERS, and from state and local agencies. Water use data are obtained from local water utilities. Production data are usually employed, but sectoral disaggregation requires the use of billing data where available.

Problems and/or Deficiencies

The explicit consideration of water conservation measures is seen as imposing a substantial requirement for more detailed water use forecasts. There is a need to better understand underlying causes for changes in per capita water use, especially as they may be attributable to sensitivity to price, income, family size, etc. The incorporation of risk analysis into project planning, where supply reliability is treated as a decision variable instead of being fixed in advance, is considered a desirable future development. The interviewees noted a need for a group within the Corps, perhaps in IWR, which would maintain a substantial level of expertise in water use forecasting, and which would be available to provide assistance to districts and divisions as required.

FORECASTS PREPARED BY OTHERS

Forecast Type and Duration

Forecasts prepared by state and local agencies, and employed by the Corps in planning efforts, may diverge from Corps requirements with respect to planning period and water use measures forecast. Frequently, such forecasts have to be extrapolated beyond their original time horizon.

Forecast Methods

State and local forecasts usually employ methods similar to those used by the Corps.

Problems and/or Deficiencies

State and local forecasts may be based on population forecasts considerably more optimistic than OBERS forecasts. They may also assume a base condition which differs from the "without project" condition used in Corps planning. State and local forecasts seldom address water conservation practices, and those that do may be inconsistent in adjusting future water use to account for such practices.

South Atlantic Division

ROLE OF WATER USE FORECASTS

The Division staff does not perform water use forecasts; it reviews forecasts prepared by District planning staffs (see Jacksonville and Savannah Districts). Water use forecasts are prepared in support of Level C multi-purpose project plans, urban studies, and regional water supply studies. The following comments summarize the experience of Division staff in reviewing district studies during recent years.

CORPS-PREPARED FORECASTS

Forecast Type and Duration

Most forecasts are for planning periods of 50 to 100 years in length. Some studies may have addressed periods as short as 20 years, but these are unusual. Forecasts for multi-purpose project planning estimate average day water use only. Urban studies sometimes include forecasts of monthly water use and of maximum day water use.

Forecast Methods

Forecasts are almost invariably of the per capita requirements type. Industrial water use, when forecast separately, may be disaggregated by industry group: per capita or per employee methods are generally used. Further disaggregation by user sector has been investigated in two recent studies, but forecasts do not appear to have been based on disaggregate methods. Where geographic disaggregation is used, county-level data are employed.

Data Sources

Per capita use coefficients may be extrapolated from water production records, but are more commonly obtained from state or local agencies (e.g., adopted from locally prepared forecasts). In some cases, coefficients have been obtained from the WRC National Assessment. Industrial coefficients may come from local or national data. Population forecasts are normally OBERS projections; where deviations can be justified projections by state or local planning agencies are used.

Problems and/or Deficiencies

The major deficiency of current methods is seen as the lack of disaggregate data on which to base analyses of water conservation. Concern was also voiced regarding the ability of current methods to reflect changes in various underlying demographic and socioeconomic trends.

FORECASTS PREPARED BY OTHERS

Division staff believe that locally prepared forecasts are not ordinarily used in Corps planning without modification. Where they are, method and data sources are essentially the same as for Corps forecasts.

Southwestern Divison

ROLE OF WATER USE FORECASTS

Water use forecasts are prepared by the Water Supply Studies Group, Southwestern Division, acting as a consultant to the districts. These forecasts are used in project planning, urban studies, river basin studies, etc. Outside consultants are sometimes used, but most forecasts are prepared by Division personnel. Forecasts prepared by state or local governments, planning agencies, or water utilities are sometimes reviewed, and may be compared to Corps forecasts, but the Corps forecasts are always prepared independently of any existing studies. The Area Economic Studies Group, Southwestern Division, is responsible for data and forecasts on population, employment, etc., for use by the Water Supply Studies Group.

CORPS-PREPARED FORECASTS

Forecast Type and Duration

Forecasts prepared for project plans are almost invariably the basis of the design of impoundments. Only long-term forecasts are prepared, therefore: the usual forecast period is 50 years. Previously, only average day water use was forecast. Recently, however, seasonal water use and maximum day water use have been forecast as well.

Forecast Methods

A standard approach is used, with comparatively minor variation to suit circumstances, for all water use forecasts. Municipal (excluding industrial) water use is forecast on a per capita requirements basis. The per capita coefficient is projected on the basis of the actual current level and the historic trend. Population projections are OBERS projections, as required by the Water Resources Council, unless other projections can be justified on the basis of local conditions.

Industrial water use is disaggregated by industry group (on a 2-, 3-, or 4-digit SIC Code basis); each group is forecast separately. Future levels of industrial water use are estimated as a function of projected number of employees, expected recirculation ratios, projected productivity, and a per employee use coefficient. The use coefficient is based on current water use data, and is assumed constant throughout the forecast period.

Seasonal water use is forecast as a fraction of total water use. The fraction may be assumed constant throughout the forecast period (set at the actual current level), or a trend may be projected. Maximum day water use is projected by applying a multiplier to average day water use.

Data Sources

Historic population, employment, industrial water recirculation, industrial productivity, and industrial water use coefficients are obtained from sources which include the U.S. Bureau of the Census, the OBERS studies, and the Texas Department of Water Resources (in Texas). Projections of these data are obtained from the same sources, or are developed by the Corps. OBERS Series "E" population projections are employed where applicable. Current and past water use data are obtained from the production records of local water utilities. In some cases, billing records for industrial users may be investigated to assist in determining industrial water use coefficients.

Problems and/or Deficiencies

Four areas were listed where improvements are sought in present forecasting practice:

1. Better data and models for preparing disaggregate forecasts are needed;
2. A sound basis for developing upper and lower bounds for forecasts is needed;
3. Better knowledge of the sensitivity of various kinds of water use to changes in price would be helpful; and
4. Better knowledge of the sensitivity of water use to changes in other explanatory variables is desired.

FORECASTS PREPARED BY OTHERS

The Southwestern Division does not use forecasts prepared by other agencies although such forecasts, when available, are reviewed and compared to Corps forecasts. Water use forecasts are routinely prepared by local water utilities and their consultants, by metropolitan planning agencies, and (in Texas) by the Texas Department of Water Resources. All local forecasts reviewed in recent years have employed a per capita requirements procedure for projecting municipal water use. Some forecasts project industrial water use separately, and the Texas Department of Water Resources may disaggregate industrial water use into sub-groups before forecasting.

Baltimore District

ROLE OF WATER USE FORECASTS

Water use forecasts are prepared by the Baltimore District for a wide variety of purposes. Project plans, reallocation studies, urban studies, the Metropolitan Washington Water Supply Study, and special studies carried out in the course of providing technical assistance to the states have all included water use forecasts. These forecasts have generally been performed by Corps staff and by consultants engaged by the Corps. Forecasts developed by other agencies are occasionally used when a parallel Corps effort does not appear justified. In recent years, this has occurred most frequently for the relatively small technical assistance studies undertaken for the states of Maryland and New York. The District has followed the practice of preparing its own forecasts in all major studies, but the use of suitable forecasts prepared by others, when available, is not ruled out.

CORPS-PREPARED FORECASTS

Forecast Type and Duration

Forecasts are used in the design of water facilities of all types, including impoundments, for preparing water resource management plans, for developing operating rules for existing impoundments, etc. Accordingly, wide ranges of forecast periods and forecast water use measures are used, as required for the various purposes. The usual forecast period is 50 years; where major facility design is not involved, however, the forecast period may be as short as 10 or 20 years. Average day water use is almost always forecast, but maximum month water use, maximum seven-day water use, maximum day water use, and average day sewer contribution have all been forecast in recent years, as required by the purpose of the study. Forecasts which address average day water use alone have not been common.

Forecast Methods

Forecast methods are stated to be flexible and freely adapted to the requirements of each study. Major criteria for choosing a method include available planning time and budget, data availability, and the nature of the planning task. Municipal water use is customarily forecast on a per capita requirement basis. The per capita coefficient may be adapted from national data, calculated from local historic data, or dictated by state planning criteria (Maryland); it may be assumed constant throughout the study period or it may vary due to extrapolation of historic trends or due to study assumptions.

Industrial water use is normally forecast as a function of number of employees, recirculation ratio, and availability of alternate sources of water. The per employee coefficient is obtained from historic water use data or from national data. Where water conservation methods have been considered in the planning process, municipal water use is disaggregated into a number of user classes (as many as ten classes in some cases).

Geographical disaggregations are frequently used where the study area includes a number of jurisdictions or water utility service areas.

Data Sources

Data and forecasts for population and employment are obtained from the U.S. Bureau of the Census, OBERS, and from state and local planning agencies. Water use coefficients are obtained from textbooks, national data, state and local agencies, and from water utility records. Both production and billing data are used (user sector disaggregation requires the use of billing data).

Problems and/or Deficiencies

The Baltimore District plans to continue its practice of adapting the forecast method to suit the task at hand. It is expected that methods will continue to evolve and change as forecasting requirements change. The District has already completed a number of studies which incorporate consideration of water conservation measures, utilizing disaggregate forecasts. No problems are foreseen other than those already encountered.

FORECASTS PREPARED BY OTHERS

Forecast Type and Duration

Forecast periods and water use measures vary according to the purpose of the forecast. The range is generally similar to that applying to Corps-prepared forecasts.

Forecast Methods

These studies almost always employ per capita requirements methods, without sectoral disaggregation. Per capita coefficients may be based on actual current water use, or may be specified by the state (Maryland, for example). Population forecasts usually do not conform to OBERS forecasts and may be revised before forecasts are used in Corps planning.

Jacksonville District

ROLE OF WATER USE FORECASTS

Water use forecasts have been prepared in support of project planning, urban studies, and water supply studies performed at the request of State agencies. In most cases, water use forecasts are prepared by consultants engaged by the Corps, and working closely with Corps planners. Locally developed forecasts have not been used in recent years.

CORPS-PREPARED FORECASTS

Forecast Type and Duration

All recent studies have used long-term forecasts, usually for a planning period of 50 years. Average day water use is always forecast; The Jacksonville Urban Study included a forecast of maximum day water use, used to determine distribution system adequacy.

Forecast Methods

The most complex water use forecasting study completed in recent years is the Jacksonville Urban Study. The forecast was disaggregated by geographical subdivision (approximately 20 districts) and by user sector (agricultural, residential, commercial, and industrial). The per capita requirements method was used for residential and commercial sectors. Aggregate per capita coefficients were obtained from records of past water use and projected into the future on the basis of study assumptions; the aggregate coefficients were then judgementally disaggregated by district, based on income and land use. Industrial water use was further disaggregated by 4-digit SIC code. Water use per employee was obtained from a 1972 local survey for each 4-digit category; these coefficients were then projected on the basis of the consultant's judgment.

Data Sources

Water use data were obtained from water production records for those uses supplied by metered public water systems. Industrial water-use (including self-supplied water) data were obtained from a 1972 survey of Jacksonville-area firms. Projections of population, employment, and income were adopted from a University of Florida study, previously accepted by EPA for wastewater facility planning purposes. OBERS forecasts were not used. Land use and other data were obtained from planning agencies.

Problems and/or Deficiencies

A major difficulty in data collection for regions like northern Florida is the easy access to groundwater. The USGS estimated that more than 40,000 individual wells were in use in 1960 in Brevard County alone. Many small water utilities operate within the city limits of Jacksonville without metering either source or customers. Firms obtain process water from unmetered wells. Many residents obtain water for lawn and garden irrigation, and sometimes for all purposes, from individual wells. These conditions make it very difficult to estimate current water use, much less to predict water use in the future.

The Jacksonville study was facilitated by the fact that most water users in the study area are served by the city water utility. Other areas in Florida typically contain numerous small water utilities and few, if any, large ones. Often, small water utilities do not meter water, or, where meters exist, are unable to recover sufficient water use data. The state of Florida does not require reporting of ground water withdrawals; records are kept of well capacity for the largest wells only. Manufacturing firms which use large amounts of groundwater may not meter withdrawals, and have been reluctant to release water use data where it exists.

These problems with basic data were believed to overshadow any present or anticipated deficiencies in the forecasting methods used.

Norfolk District

ROLE OF WATER USE FORECASTS

Most recent experience with water use forecasts in the Norfolk District has been with a single current study, authored by Congressional resolution, which is attempting to determine the future water supply needs of the Norfolk metropolitan area. Almost five years of planning have so far failed to produce a generally acceptable estimate of future water needs, in spite of several changes of forecasting techniques. The following sections, therefore, will review the key features of this effort, which is being performed by a consultant, under the direction of Corps staff.

CORPS-PREPARED FORECAST

Forecast Method

The first attempt at forecasting water use in the Norfolk area was completed in 1978. It utilized a conventional per capita requirements approach, with geographic disaggregation according to political jurisdiction. Most assumptions were derived from existing forecasts for the various jurisdictions which had been prepared by the planning district, the utilities, etc. In adapting and combining these forecasts, population projections were altered to conform to OBERS as modified for expected changes in military population, and projected growth rates in per capita coefficients were adjusted for internal consistency.

The second attempt, begun in early 1979 in response to Division criticism of the first forecast, was based on a sectoral, as well as geographic disaggregation of water use, and on explicit consideration of existing and future water conservation measures. Since suitable billing data were not available, the Corps contractor undertook a sampling program, analyzing individual customer accounts according to sampling frequencies ranging from 0.33 percent to 2.0 percent. Water use was determined for each sampled customer for 1975 and for 1979, and various data were collected, including type of occupancy, family size (for single-family residential), lot size (also for single-family residential), etc. In the case of military bases, post engineers were asked to provide a judgmental disaggregation of total water use according to use sectors. All significant industrial customers were analyzed separately.

The 1975 disaggregation appeared to provide the most useful basis for a forecast, as it proved to be internally consistent and to represent a year of essentially normal weather conditions. Water use coefficients were calculated for each user class, based on population in the residential classes, employment in the commercial class, gross product originating in the industrial class, and on both bachelor and married populations for military bases. At the present time, there is no general agreement on the proper means for forecasting future trends in these water use coefficients. Projecting them at their 1975 values produces a forecast which appears to be already in error by 1980. No historic data are available which would permit extrapolation of past trends. Completion of the study presently (January 1981) awaits resolution of this problem.

Problems and/or Deficiencies

The first forecast effort was criticized for the simplicity of its per capita approach and for lack of explicit consideration of the effect of water conservation measures, including those already implemented in the area.

The second approach, designed to correct these deficiencies, has encountered substantial difficulty in obtaining required data. A time-consuming sampling procedure was needed to estimate water use coefficients for the various user classes, since no local utility had coded accounts according to user class. Furthermore, computer billing has just been adopted by several of the utilities within the past few years. Even after the base values of the water use coefficients have been determined, there is no empirical basis for projecting future changes in these coefficients.

St. Louis District

ROLE OF WATER USE FORECASTS

Recent water use forecasts in the St. Louis District have been prepared for use in project planning. These forecasts have been prepared for the Corps by consultants. Locally developed forecasts have not been used, except for comparison purposes when appropriate.

CORPS-PREPARED FORECASTS

Forecast Type and Duration

Recent forecasts have been prepared for the purpose of designing impoundments, pipeline diversions, or ground water source facilities. The usual forecast period has been 100 years, with water use estimated at 10-year intervals throughout the period. Only average day water use is forecast.

Forecast Methods

A per capita requirements method is used for all forecasts, with municipal and industrial water use usually being projected as a single sum. Where industrial water use is separately considered, it is also projected on a per capita basis. Per capita coefficients are assumed to increase from current levels to some higher future level, then to remain constant for the balance of the planning period. Where a separate per capita coefficient is provided for industrial water use, it may be assumed to remain constant.

Data Sources

Population data and projections are obtained from the U.S. Bureau of the Census, OBERS, the metropolitan area planning agency, and from the St. Louis County Planning Department. Water use data are obtained from local water utility production records.

Problems and/or Deficiencies

The interviewees noted a need for guidelines regarding the appropriate level of detail and planning effort to be devoted to water use forecasting under different planning conditions and stages. They also indicated a need for criteria for judging the suitability of forecasts prepared by other agencies. The relative inexperience of the typical Corps planner was pointed out: most water use forecasts are performed or directed by a Corps planner with little or no previous experience in water use forecasting. Guidance and criteria must be comprehensive and explicit if uniform and satisfactory procedures are to be used.

FORECASTS PREPARED BY OTHERS

The St. Louis District has no recent experience with forecasts prepared by other agencies.

San Francisco District

ROLE OF WATER USE FORECASTS

Recent water use forecasts in the San Francisco District have been prepared for use in project planning and design. Forecasts are normally prepared by district planners, or by Corps consultants under the direction of district planners, although State and local water use forecasts may be incorporated into Corps forecasts.

Most water supply purposes in California include significant agricultural water supply. Agricultural water use is forecast by the Water and Power Resources Service of the U.S. Department of the Interior, and is only reviewed by the Corps to insure consistency of assumptions and general reasonableness. Agricultural water use forecasting techniques are not discussed here, therefore.

CORPS-PREPARED FORECASTS

Forecast Type and Duration

Water use forecasts have, in recent years, addressed average day water use, seasonal water use, maximum day water use, and average contribution to sewer flow. Most forecasts are long-term projections, estimating water use for periods ranging from 30 to 100 years in the future. Some studies, especially those dealing with management or reallocation of existing facilities, may be for medium-range periods (10 to 30 years).

Forecast Methods

Forecasts are disaggregated geographically (according to political jurisdictions, for example) and by user sector (residential, commercial, and industrial). Residential and commercial water uses are forecast by the per capita requirements method. Where possible, past trends in sectoral per capita coefficients are extrapolated to give future coefficient values.

Industrial water use is further disaggregated into groups of related firms. Future water use for each group is estimated on the basis of a per unit output coefficient. The coefficient value is obtained from analysis of past water use levels, or it may be predicted on the basis of other information, such as national data, trends elsewhere, judgment, etc.

Data Sources

Water use data are obtained from local water utilities and water districts. In most cases, customer billing data are utilized; disaggregation by customer class is performed by the utility. OBERS population forecasts are utilized unless there is reason to doubt their appropriateness; in these cases, State forecasts are relied upon in place of OBERS. State forecasts may also be used to interpolate OBERS forecasts for small areas.

Problems and/or Deficiencies

Difficulties have been encountered in forecasting population for small areas, and in estimating the impact of water conservation measures on future per capita water use. It is felt that more effective training for water use forecasting is required, at both district and division level. It is also suggested that a format for exchange of water use forecasting information among districts and divisions be established. District planners indicated that they had no knowledge of which other districts or divisions faced similar forecasting problems, or how those problems were being handled.

FORECASTS PREPARED BY OTHERS

The San Francisco District makes frequent use of water use forecasts prepared by State agencies, or by local governments or water districts. Typically, these forecasts are the source of data or assumptions for Corps-prepared forecasts, although local forecasts may sometimes be incorporated into Corps forecasts. It is pointed out that the use of local forecasts, or data and assumptions obtained from local forecasts, helps to assure local support for the Corps forecast, as well as giving the Corp access to data and information which may be more readily available to local agencies. Forecasting methods used by state and local agencies are believed to be essentially the same as those employed by the Corps.

Savannah District

ROLE OF WATER USE FORECASTS

The Savannah District performs water use forecasts in conjunction with urban studies, river basin studies, analyses of requests to withdraw water from existing projects, and multipurpose project planning. Recent project planning activities have not included water supply purposes, however. The most prominent recent water use forecasts are those associated with the Atlanta and Savannah Urban Studies. Forecasts are prepared by the Corps, or by consultants engaged by the Corps and working under the direction of Corps planners. No recent use has been made of locally prepared forecasts in Corps planning.

CORPS-PREPARED FORECASTS

Forecast Type and Duration

Forecasts normally deal with average day water use. The Atlanta Urban Study also projected maximum day water use, and water use by calendar month. All recent forecasts have been for the long-term future, ranging from 30 to 50 years from the base year.

Forecast Methods

Forecasts are geographically disaggregated, by political jurisdiction (Savannah) or by transportation planning district and census tract (Atlanta). Forecasts are also disaggregated by user sector (residential, commercial, public and industrial). The industrial sector has been further disaggregated by SIC code at the 2- and 3-digit level for the Savannah study. Residential, commercial, and public sectors are forecast by the per capita requirements method. The industrial sector has been forecast on the basis of water use per acre of industrial land (Atlanta) and of water use per employee (Savannah). Water use coefficients have generally been obtained from national or regional data, although the final forecast may be calibrated against local data. Attempts have been made to incorporate consideration of water conservation measures.

Data Sources

Per capita coefficients are obtained from regional data in the U.S. Water Resources Council's First National Assessment. These coefficients apply to residential, commercial, and public water use. The only exception is the Savannah study, where data from a sample residential area were used to estimate residential water use at 85 gallons per capita per day. Per employee coefficients for industrial water use were obtained from the U.S. Census of Manufacturers. In the case of Atlanta, the population projection was prepared by the Atlanta Regional Commission, the area planning agency. The Savannah study uses four different population growth scenarios, which include the OBERS forecast as one of the possibilities.

Problems and/or Deficiencies

Comparison of actual water use data for Atlanta with a "backcast" obtained from the forecasting model revealed some discrepancies, especially in the case of commercial use in the city of Atlanta. Adjustments were made to the forecasts as a result of this comparison. Concern has been expressed regarding the impact of such water conservation measures as the recently enacted changes to the state plumbing code. No information is at hand which would permit calculating the required adjustment to per capita water use.

A need for expert technical assistance on water use forecasting problems was discussed. Training courses dealing with computer programs for forecasting water use are considered desirable, but it was noted that courses should be practice-oriented and should include hands-on experience with the computer programs themselves.

FORECASTS PREPARED BY OTHERS

No recent use has been made of locally prepared water use forecasts.

APPENDIX C

THE MAIN II SYSTEM

The MAIN II System was developed in 1969 by Hittman Associates, Inc., of Columbia, Maryland, with funds provided by the Office of Water Resources Research (later Office of Water Research and Technology). The MAIN II System is, in turn, based on earlier work at The Johns Hopkins University, at Hittman Associates, and by other investigators. It is a computerized forecasting system which contains a range of forecasting models, parameter generating procedures, and data management techniques. The forecasting system and its application are described in Hittman Associates (1969), Boland (1971), and Boland (1978).

Among the basic features of the MAIN II System are the high level of disaggregation of water users and the considerable user flexibility in selecting forecast methods and assumptions. Because of the high level of disaggregation, the system is able to reflect water use differences between communities with different sets of water-using activities, even though historic water use data is not provided. Little or no calibration has been required, even though the system has been applied to a wide range of towns and cities in many parts of the U.S. User flexibility is provided so that the system can be used even where some or much of the specified data may be unavailable.

The MAIN II System divides urban water users into four sectors: residential, commercial-institutional, industrial, and public. Each use class is further disaggregated for forecasting purposes. The residential class is separated into those users groups with and without water meters, and into those with and without public sewers. Commercial, institutional, industrial, and public users are categorized by the nature of their activity, with up to 280 different categories available (coefficients, based on national or typical use patterns, are provided for 132 categories).

A mixture of forecasting techniques is employed (see Table C-1). Some classes are forecast by means of demand models containing a number of explanatory variables including price (for residential users with water meters). Other categories are estimated by means of more simplistic requirements models, usually of the unit use coefficient type. Demand models used for residential categories are adapted from the work of Howe and Linaweaver (1967) (see Table C-2). Unit use coefficients for commercial and institutional water use categories are drawn from Wolff et al. (1966), (see Table C-3). Industrial water use is based on employment by SIC category.

In each time period, water use is calculated as a function of a set of parameters, or explanatory variables. Each of these parameters must be projected to the forecast year so that the water use forecast can be calculated. MAIN II provides three alternative approaches to estimating future values for the water use coefficients:

1. Projection by internal growth models;
2. Projection by extrapolation of local historic data provided by user; and
3. Use of projections made external to the MAIN II System, and provided by user.

Any of the three methods can be used for any parameter, for any forecast year, independent of methods used for other parameters or for other forecast years.

TABLE C-1. Organization of the MAIN II System

Sector	Water Use Category	Computational Method
Residential	Metered, Sewered Residences Metered, Septic Tank Residences Flat Rate, Sewered Residences Flat Rate, Septic Tank Residences	Multivariate Demand Models
Commercial/ Institutional	Up to 50 user categories, such as: Hotels, Restaurants, Elementary Schools, Hospitals, Office Buildings	Unit Use Coefficients
Industrial	Up to 200 user categories, presently including: 104-SIC 3-digit manufacturing industry categories	Unit Use Coefficients
Public/ Unaccounted	Up to 30 user categories, such as: Distribution System Losses, Free Service, Airports	Unit Use Coefficients and Per Capita Coefficients

TABLE C-2. Example of Demand Model

Mean Annual Sprinkling Use for Metered, Sewered Residences In United States, East of 100th Meridian

$$q = (0.39 \times 0.164B^{-0.793} \times (E - 0.6R)^{2.93} \times p_s^{-1.57} \times V^{1.45})N$$

Where:

q = mean annual water use, gpd

B = irrigable land per residence, acres/unit

E = potential summer evapotranspiration, inches

R = summer precipitation, inches

p_s = marginal price of water in effect in summer ¢/1000 gal.

V = median market value of residences

N = number of residences in value group with median V

TABLE C-3. Example of Unit Use Coefficient

Mean Annual Water Use for Hospitals

$$q = C \times P$$

where:

C = water use coefficient for hospitals, mean annual = 346 gpd/bed

P = water use parameter for hospitals, number of beds

q = mean annual water use for hospitals, gpd

During the development of the system, MAIN II was used to "backcast" water use for several communities, that is, to estimate water use based on known values of the water use parameters. Table C-4 summarizes the results of these experiences, showing rather close agreement between predicted and actual levels of water use, especially for the larger cities. Errors on estimates of aggregate use range from 0.4 percent to 10.4 percent. As noted earlier, no water use data is required to use the MAIN II System. Yet it successfully reproduced water use in areas where average use ranged from 70 to 170 gallons per person per day.

In order to use the MAIN II System, a complete set of data must be provided for the base year. At the maximum level of disaggregation, this requires data on number of residences in each of a set of home value ranges, per capita income, water price, average lot sizes, a variety of parameters describing commercial and institutional activity, and industrial employment by SIC category. Where some of these data are not available, more aggregated models can be selected. The more aggregated the models, the fewer the data requirements, and the greater the need for calibration against local water use data.

For each forecast year, a considerable range of options is available. At one extreme, the user can supply only population and income for the forecast year; the MAIN II System will generate values for all other parameters internally. At the other extreme, the user may provide a full set of projected values for all water use parameters. Between these extremes, any data which is available for the forecast year may be used, with the knowledge that the system will complete an internally consistent set of parameter forecasts.

TABLE C-4. Application Experience with MAIN II System

Location	Actual Demand (mgd)	MAIN 2 Estimate (mgd)
Baltimore, Maryland (1963 data)		
Residential	97.3	95.2
Public-Commercial	19.6	19.2
Industrial	42.0	45.1
TOTAL	158.9	159.5
Park Forest, Illinois (1959 data)		
Residential	1.68	1.49
Commercial	0.15	0.15
Park Forest, Illinois (1961 data)		
Residential	1.70	1.58
Park Forest, Illinois (1962 data)		
Commercial	0.18	0.15
Park Forest, Illinois (1963 data)		
Residential	1.72	1.58
Commercial	0.19	0.17
Park Forest, Illinois (1965 data)		
Residential	1.91	1.75
Commercial	0.21	0.19
Park Forest, Illinois (1967 data)		
Residential	1.91	1.84
Commercial	0.21	0.20
Baton Rouge, Louisiana (1965 data)		
Residential	n/a	14.0
Commercial	n/a	5.20
Public and Unaccounted	n/a	4.36
TOTAL	23.8	23.6
Kings Heights District Anne Arundel County, Maryland (1968 data)		
Residential and Commercial	0.31	0.32

The MAIN II System is available from the National Technical Information Service (NTIS) as follows:

PB-190 275 — Forecasting Municipal Water Requirements:
The MAIN II System - Vol. I.

PB-190 276 — Forecasting Municipal Water Requirements:
The MAIN II System - Vol. II, User's Manual.

PB-192 420 — Library Tape

PB-192 421 — System Tape

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