North Atlantic Regional Water Resources Study

Appendix T
Plan Formulation

NORTH ATLANTIC REGIONAL WATER RESOURCES STUDY COORDINATING COMMITTEE
MAY 1972

The North Atlantic Regional Water Resources (NAR) Study examined a wide variety of water and related land resources, needs and devices in formulating a broad, coordinated program to guide future resource development and management in the North Atlantic Region. The Study was authorized by the 1965 Water Resources Planning Act (PL 89-80) and the 1965 Flood Control Act (PL 89-298), and carried out under guidelines set by the Water Resources Council.

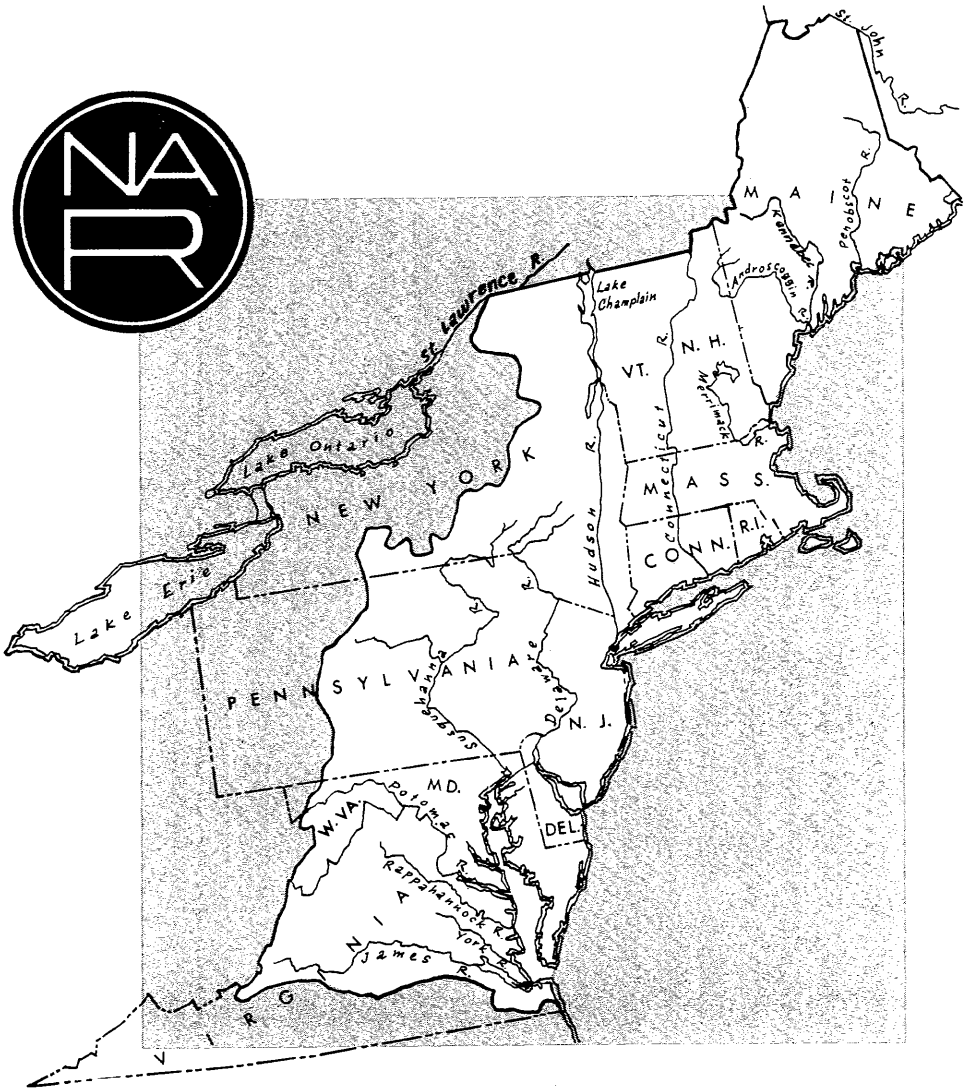
The recommended program and alternatives developed for the North Atlantic Region were prepared under the direction of the NAR Study Coordinating Committee, a partnership of resource planners representing some 25 Federal, regional and State agencies. The NAR Study Report presents this program and the alternatives as a framework for future action based on a planning period running through 2020, with bench mark planning years of 1980 and 2000.

The planning partners focused on three major objectives -- National Income, Regional Development and Environmental Quality -- in developing and documenting the information which decision-makers will need for managing water and related land resources in the interest of the people of the North Atlantic Region.

In addition to the NAR Study Main Report and Annexes, there are the following 22 Appendices:

A. History of Study
B. Economic Base
C. Climate, Meteorology and Hydrology
D. Geology and Ground Water
E. Flood Damage Reduction and Water Management for Major Rivers and Coastal Areas
F. Upstream Flood Prevention and Water Management
G. Land Use and Management
H. Minerals
I. Irrigation
J. Land Drainage
K. Navigation
L. Water Quality and Pollution
M. Outdoor Recreation
N. Visual and Cultural Environment
O. Fish and Wildlife
P. Power
Q. Erosion and Sedimentation
R. Water Supply
S. Legal and Institutional Environment
T. Plan Formulation
U. Coastal and Estuarine Areas
V. Health Aspects

Appendix T
Plan Formulation



Prepared by

North Atlantic Regional Water Resources Study Group
North Atlantic Division
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for the

NORTH ATLANTIC REGIONAL WATER RESOURCES STUDY
COORDINATING COMMITTEE

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CHAPTER 1: Introduction and Summary

This Appendix describes the plan formulation process used in the NAR Study. This description will facilitate evaluation of the methods and hence of the recommendations of the study and will facilitate the utilization of the formulation process in other studies or in revisions of the NAR study.

The Appendix is divided into seven chapters, each covering a phase of the plan formulation process. The process is described through papers presented at Coordinating Committee meetings, sample worksheets and other materials produced during plan formulation, and through introductory and analytic material prepared especially for this Appendix.

PLAN FORMULATION IN THE NAR

The plan formulation process used in the Study can be divided into three broad stages. Each stage is described in this introductory chapter to provide a narrative framework for the materials in the chapters that follow. While the stages were not completely separated in time in the sense that all of the activities of one stage were completed before the activities of the next began, the dates given provide a picture of the time required for each stage of plan formulation.

In addition to the material included in this Appendix, information on the planning process is contained in the Main Report of the Study, especially in chapters 1 and 5; in the History of the Study, Appendix A, which lists Coordinating Committee and Board of Consultants meetings; and in Annexes 1 and 2 to the Main Report.

THE FIRST STAGE OF PLAN FORMULATION (September 1968 - June 1969)

Plan formulation in the NAR study began with preparations for and discussions at the fifth and sixth meetings of the Coordinating Committee held in September 1967 and May 1968. At these meetings the Committee approved the use of multiobjective planning for the NAR, including the use of the national income (efficiency), regional development and environmental quality objectives for plan formulation. The Committee also approved the recommendation of the staff that three alternative sets of estimates of the planning elements (needs, sources, devices) should be developed. Each set was to represent desired levels of the planning elements for benchmark years with a somewhat exaggerated emphasis on one of the planning objectives. These three sets of

estimates were to provide the basis for the development of a recommended plan for the NAR, a plan based on a mix of objectives.

Three papers written early in this stage of plan formulation remain accurate descriptions of the process, and these constitute Chapter 2 of this Appendix. The papers are: "The Proposed Rationale for Plan Formulation," a description of the multiobjective approach; "The Structure of Plan Formulation," a description of the types of interrelationships among needs, source and devices required for planning; and "Plan Formulation: Rationale, Structure and Procedures," a summary of the three proposed stages of plan formulation.

This first stage of plan formulation was the longest of the three stages. Estimates of needs, sources and devices for each of the three alternative programs were developed independently by the agencies responsible for studying different purposes. Multiobjective methods in planning were new and it was throught to be desirable to encourage all participants to explore freely alternative methods of contributing to the planning process. In addition, because of the absence of the large scale computional models later developed, centralized formulation of alternative sets of estimates would have been difficult at this stage.

A Plan Formulation Work Group was established with representation from each of the member stages and agencies of the Coordinating Committee. Meetings held during plan formulation were primarily meetings of this group. For both budget reasons and reasons of efficiency members of the Plan Formulation Work Group ordinarily attended only those meetings relevant to their technical or geographical areas although all members were free to attend all meetings of the group.

The first step in the Work Group meetings for stage one was the presentation of estimates of needs, sources and devices for water and related land management and development for each area, for each objective, and for each benchmark year. The estimates were presented by the work group members from the agency that had developed them. These estimates were then discussed by all members of the Work Group and tentative agreements were reached on appropriate levels of the planning elements for each objective and benchmark year. Then, following each meeting, the staff assembled the estimates agreed upon and made minor adjustments as appropriate. This procedure for first stage plan formulation was developed and tested in an experimental meeting before the series of actual plan formulation meetings began.

After the entire series of first stage Plan Formulation Work Group meetings was completed the information developed was assembled, modified as required by inquiries to the agencies, and reproduced for review. This information, published as the "First Report of Plan Formulation," included descriptions of the assumptions underlying pro-

jections for each need and summaries of the implications of each of the Programs emphasizing alternative objectives for various areas. This report was issued serially between May and August, 1969 and consisted of more than 500 pages of text and tables.

Excerpts of material from the "First Report on Plan Formulation" and related material form Chapter 3. The chapter includes Memorandum 69-28 to Members of the Coordinating Committee, which introduced the report; an abstract of the report; a summary of the Work Group meetings; the material that was distributed for Area 9 (Southeastern New England) as an example of the material prepared in the first stage; and an evaluation and discussion of the plan formulation material.

One important lesson learned during the first stage of plan formulation was that adequate computational techniques would have to be developed for use in the remainder of the Study. It became quite clear that the amount of information required for multiobjective analysis could not be successfully manipulated without the use of large computational models. Hence the development of these models tended to occupy more and more staff time in the Study. The requirements of sensitivitly analysis, which appears to be a natural concomitant of multiobjective planning, also strongly suggested the need for computational models.

THE SECOND STAGE OF PLAN FORMULATION (June 1969 - September 1970).

The second stage of plan formulation centered about the development of the demand and supply models and the improvement and expansion of the data and projections developed in the first stage. The demand model projects regional water needs or requirements; the supply model, identifies least cost supply configurations for any set of projected requirements. Generally the work accomplished in the second stage was done without Work Group meetings; instead, extensive contact was maintained between the planning staff in New York and the various cooperating agencies and stages. Each agency assumed responsibility for the improvement and development of the material that it had presented during the first round of plan formulation. During this stage worksheets were introduced into the planning process that were designed to facilitate estimates of and comments upon the nature of interactions among planning and management devices and the positive and negative effects of these devices on needs and resources.

Revised planning materials were distributed for review as the product of the second stage of plan formulation. Chapter 4 presents the planning materials package for Area 9 (Southeastern New England) as it appeared at the end of the second stage. This is preceded by an introductory memorandum, Memorandum 70-14, and followed by a brief analysis entitled "The Process of Evaluating Device Interactions."

THE THIRD STAGE OF PLAN FORMULATION (September 1970 - May 1972)

This stage began with six Plan Formulation Work group meetings held in or near one of the State capitals in the NAR. The purpose of these meetings was to formulate draft programs for a mixture of objectives for each of the NAR areas on the basis of the materials developed in stage two. The locations for the meetings were chosen to encourage the participation of large numbers of personnel from State and regional planning and water agencies. The series of work group meetings was preceded by meetings of NAR staff with personnel from each of the States; these meetings were for the purpose of familiarizing State personnel with the demand model outputs that were used during the work group meetings.

Following this series of meetings draft area programs were prepared by the NAR staff and agency staffs on the basis of agreements at the meetings. In the course of the third stage the program for each area was rewritten and reviewed several times as new information was obtained and comments were received.

The outputs from the demand model, which had first become available during the second stage of plan formulation, were fully incorporated into plan formulation during the third stage, beginning with the series of work group meetings. Outputs from the supply model took longer to obtain than had been anticipated and the third stage was extended to permit the full use of these results in plan formulation. A special work group meeting was held in 1972 to consider supply model results and to decide upon final runs reflecting mixed objectives. These runs were made by the NAR staff and the results were incorporated into the mixed objective area programs.

The members of the Coordinating Committee met during this stage sitting as the Plan Formulation Work Group. From the analysis of trade-offs made at this meeting emerged the mix of objectives on which the recommended NAR program is based.

The results of the third stage of plan formulation include the 21 Area Programs (Annex 1 to the Report); the Regional Program (Chapter 8 of the Report); and the basis for the Findings and Recommendations of the Coordinating Committee (Chapter 9 and 10 of the Report).

Materials relating to the third stage of plan formulation included in this Appendix are in three chapters.

Chapter 5 includes Plan Formulation Memorandum 17, which lists the work group meetings held early in the third stage, along with the meetings between NAR staff and the agencies of the NAR states that were held preparatory to these work group meetings. This memo-

randum is followed by Memorandum 71-13, which presents a draft area plan formulation report for the James River Basin, Area 21. The last item in this chapter is Plan Formulation Memorandum 20, containing the reference materials list for the Plan Formulation Work Group meeting at which supply model outputs were evaluated and recommendations for final runs of this model were made.

Chapter 6 includes a series of papers on the demand model: "Introduction to the Demand Model;" "The Imput-Output Model for Estimating Water Demand," "Description and Formulation of the Model," "The 50 Planning Sub-areas," "Derivation of Demand Model Imput Data," "Sequence of Model Runs and Analysis," and "Variant Run Analysis." Together these papers given a full picture of the nature and utilization of the demand model in the NAR study. The complete user's manual for the model is available as a separate publication, NAR Special Publication #1.

Chapter 7 includes similar papers on the supply model: "Introduction to the Supply Model," "Description and Formulation of the Model," "Development of Supply Model Input Data," and "Sequence of Model Runs and Analysis." The complete report on model formulation for the supply model is available as NAR Special Publication #2.

IMPLICATIONS OF THE NAR METHODS AND MODELS

The NAR plan formulation methods and models are based on general planning principles adapted to the special circumstances of the framework planning effort. For the NAR the general principles include the multiobjective approach and the related idea that planning must be a series of iterative interactions between the preferences of people and the investment and management opportunities open to them. The particular circumstances that shaped the methods used in the NAR include most notably the cooperative and framework nature of the plan, and the staff and budget limitations under which the planners operated. The NAR plan formulation methods and models may be of use to other water resources planners both in demonstrating on an overall basis how one group of planners attempted to deal with the complex multiobjective nature of planning in a cooperative context and on the more particular basis of providing methods and tools that may be borrowed for other planning efforts. The papers in this appendix and materials such as the beginning and final budgets and the lists of meetings in the History of the Study (Appendix A) should prove useful in providing a picture of the NAR planning process for both of these purposes.

The types of plans to which aspects of the NAR planning methods may be relevant vary from framework plans to plans of a rather detailed, project-oriented type.

A specialized use of the methods and models is to serve as a comprehensive basis for updating the NAR study itself. They provide the groundwork for a continuous planning process in the NAR region. This is an important step forward in water resources planning, where frequently planning teams have been disbanded following the completion of a report without leaving behind them a set of methods and models that would permit plan reformulation in response to changing conditions.

Certain broad ideas of the NAR planning process, such as the embodiment of the iterative process of integrating preferences and possibilities in water management and development in a series of work group meetings, should be widely applicable to other planning efforts. More narrowly defined tools, such as the specialized worksheets used in the meetings can serve as the basis for tools appropriate to other planning efforts.

The two main computational models used in the study, the demand model and the supply model, are among the principal reflections in the study of the idea of utilizing an explicit planning process subject to repetition in the future, and some brief comment on how they might be used for replanning the NAR and for other water resource planning efforts will illustrate some of the possibilities for borrowing NAR methods and models.

For replanning the NAR, the demand model could be easily updated with the use of the recently available 1963 national input-output table, reduced to a regional table by the methods used to regionalize the updated 1958 table that is currently in the model. In addition, the model could be used in its present form, with only the alteration of certain output headings and the input of vectors of pollution production coefficients, to give estimates of the projected levels of various pollutants in the sub-basins of the NAR. The supply model can be utilized with updated cost of yield functions. Further, with some additional reformulation, the supply model could be converted into a net benefit maximizing model, a form with which further insight into the optimal configuration of management and investment devices for the NAR could be obtained.

For other planning efforts, the demand model can serve as a water withdrawal or pollution loading model for other areas where input-output tables are available or can be derived from national coefficients; and, where such tables are not available, it can be used as a flexible projection model based on other types of projection mechanisms. The supply model can be utilized generally as formulated now for many other regions, with new input data and alternative formulations of the equations to suit alternative import-export possibilities.

CHAPTER 2

DEVELOPMENT OF PLAN FORMULATION PROCEDURES

NORTH ATLANTIC REGIONAL WATER RESOURCES STUDY

THE PROPOSED RATIONALE FOR PLAN FORMULATION

North Atlantic Regional Study Group
North Atlantic Division, Corps of Engineers

August 1967

T-9

THE PROPOSED RATIONALE FOR PLAN FORMULATION

The concept of framework planning for three objectives: national income; regional development; and the quality of the environment; was discussed at the fourth meeting of the Coordinating Committee. Members of the Committee and others interested have commented informally on this concept of planning. The Study Group now recommends that the Committee approve this approach as the rationale for plan formulation, using the three objectives stated. The Study Group recommends the rationale at this time in line with its intention to introduce new planning problems and progress reports at each meeting of the Committee, and to make recommendations on each topic at a subsequent meeting. This two-stage approach to new material is intended to provide orderly and continuous progress toward the completion of the framework plan, while assuring full participation in the planning process by all members of the Committee. In addition, this approach will insure that the wishes of the Committee will continue to guide the work of the Study Group.

The proposed rationale is summarized in this report for the convenience of the Committee. If the proposed rationale is adopted, material similar to the contents of this report will form part of Appendix T, "General Program and Alternatives."

A rationale is a conceptual basis for plan formulation rather than a detailed guide to action. The next step in planning after the adoption of a rationale is the development of a more detailed structure within which planning data can be integrated in the actual work of plan formulation. A preliminary report on this structure is attached and is intended to serve as the basis for discussion of this new topic at the fifth meeting of the Committee.

The fundamental reason for adopting a multiple-objective approach to water resources planning is that every water resource investment affects a variety of social objectives, even if it is designed to attain only one objective. This is true of framework planning as well as of detailed project planning. The proposed rationale for planning is designed to take account of the multiple effects of water resource investment. Since many objectives will in any case be affected by an investment, the prudent course of action is to select those objectives that are of importance, and then to design investments that best achieve some desired combination of those objectives. This holds for framework planning as well as project planning, although at the framework level specific investment projects are not designed. The differences between framework planning and project planning lie not in the conceptual structure of planning, but rather in the level of generality at which plans are formulated.

Within the multiple-objective approach to framework planning, three steps can be distinguished. First, the important objectives of

planning must be identified; second, the extent to which these objectives can be reached through water resource investment within the planning area must be discovered; and third, the best mixture of benefits toward the objectives must be decided upon. These steps are discussed in turn in what follows.

The three proposed objectives of planning: national income; regional development; and environmental quality; have been proposed for several important reasons. First, they are objectives that might be significantly affected by water resource development in different subregions of the North Atlantic Region. Second, they are objectives that are of concern to the Coordinating Committee. Third, they are objectives that have been of broad interest to those dealing with a variety of public investment sectors in the United States in recent years. Finally, these goals are comprehensive. By focussing our effort on them almost all of the specific effects of water resource investment that we might wish to consider will be included within the process of plan formulation. It is therefore proposed that these three objectives should be explicitly handled in terms of the proposed rationale. Other objectives that might be relevant at various stages in planning can be dealt with on a more informal basis.

The <u>national income objective</u> of planning is the provision of increases in the national income through investment in water resources development. This objective is attained to the extent that water resources system outputs meet demands expressed in market terms or in terms of statistically constructed markets. An example of a market demand for a system output is industrial demand for water supply; an example of demand in terms of statistically constructed market is demand for recreation outputs not sold on a market basis. Meeting demands of this kind has been the traditional objective of water resource development, and its attainment has usually been measured by counting "primary" benefits. Another way of defining the objective is to say that it represents the best allocation of economic resources in market terms.

Although the national income objective is a broad one, and in attaining it some progress may well be made toward the regional and environmental quality objectives, these other objectives are not explicitly included in national income considerations, and so must be dealt with separately.

The <u>regional objective</u> of framework planning is the attainment of some desired pattern of regional income or development through water resources investment. This objective is attained to the extent that water resource investment provides specified regional income flows or specified patterns of regional development. An example of a regional objective is the desire to increase the incomes of the indigenous residents of an area through water resources investment. Another example is the desire to increase the total output of a designated region. In

general, patterns of this kind are not the natural result of investing to attain the objective of national income growth or other objectives. Thus, attaining a given regional objective ordinarily results in a lesser degree of attainment of other objectives than would occur in the absence of the regional goal. The regional goal to be used in plan formulation for the North Atlantic Region should evolve from consideration both of desired regional patterns and of planning results indicating what regional patterns are achievable through water resource development. The Committee is already involved with one regional consideration, since part of Appalachia is included in the North Atlantic planning region. Regional considerations have been involved to some extent in water resource planning as "secondary" benefits; in the framework plan, they would be involved more explicitly in the process of plan formulation.

The environmental quality objective of framework planning is the improvement of the quality of the environment through water resource investment in the North Atlantic Region. This objective includes not simply preservation but, perhaps more important, positive measures to create an improved living environment. The intention of including this objective is to insure that the effects of water resource development on "human ecology," the relation between man and his natural and manufactured environment, are carefully defined and evaluated. The extent to which the environmental quality objective is attained cannot be readily expressed in the measureable terms that might be used for the national income and regional objectives. But there are some systematic ways in which environmental quality effects can be assessed. It is possible that the Committee will find a broad range of agreement on whether certain effects are favorable to the quality of the environment, and what the relative importance of various effects might be, both in terms of other environmental quality effects and in terms of the other objectives of planning. The relationship between water resource development and environmental quality will differ between the subregions of the area. For example, problems of environmental quality differ as between relatively urban and relatively rural areas. The environmental quality objective represents a comparatively new objective in water resources development, although it has always been present in the form of supplementary comments in project reports, particularly with respect to the preservation aspect of the objective.

Given objectives, the second stage of framework planning becomes relevant: to what extent can the objectives be attained through water resource investment within the planning area? Each of the proposed objectives of the framework plan provides a direction in which planning might move. Most potential water resource investments, or lack thereof, will have effects, positive or negative, in each of the three directions. Faced with technologic and resource potentials, and with economic and demographic projections, the planner has to determine how far it is possible to move in each direction.

There are a very large number of combinations of net benefits toward the three objectives that might be attained. These combinations of benefits toward the objectives of plan formulation can be represented geometrically. In the diagram, each direction or axis represents net benefits toward one or another of the objectives of planning. The origin represents zero net benefits toward every objective, and movement in the direction of the arrow on each axis represents positive net benefits on that axis. There is a surface at varying distances from the origin that represents the most that can be achieved in the direction of any combination of the three objectives. This surface is "efficient" in the sense that a point on it represents the greatest possible degree of attainment of one objective given specified degrees of attainment of the other two objectives. The key problem of plan formulation is that little or nothing is known about the shape or location of this surface in any planning situation before planning actually begins. The surface drawn in the diagram, therefore, is simply illustrative.

Thus the next step in planning following the selection and definition of objectives amounts to discovering something about this surface. This second step of the rationale is the heart of framework plan formulation. The degree to which it is successfully completed largely determines the degree of confidence with which a final plan can be recommended.

With limited funds, time, and personnel, the practical objective of plan formulation is to discover as much as possible about what can be done with a reasonable expenditure of resources. The Study Group's proposal that three preliminary plans be formulated is designed to meet this practical objective. Each plan will be designed to explore one area of what can be done through water resources investment. Each will be formulated to emphasize one of the three objectives, without neglecting the other objectives of planning. In addition, the effects on each of the three plans of varying key economic, demographic, and technological assumptions will be considered. An illustrative position for each of the preliminary plans is shown on the diagram.

With the information gained from the three preliminary plans, the third and last step in the planning rationale can be approached. With insight into what can be accomplished, the Committee can move to a decision on what should be accomplished through water resources development in the North Atlantic Region. This decision should be expressed in terms of a desired combination of benefits, at the framework level of generality, toward objectives. This decision will constitute the recommended plan. Because of the way in which the three preliminary plans are to be formulated, each emphasizing one objective, the Committee will have available to it information about three widely spaced areas of the attainable benefit combinations. This being the case, the Committee will probably wish not to select one of the preliminary plans as the final plan, but rather to use the information from these three

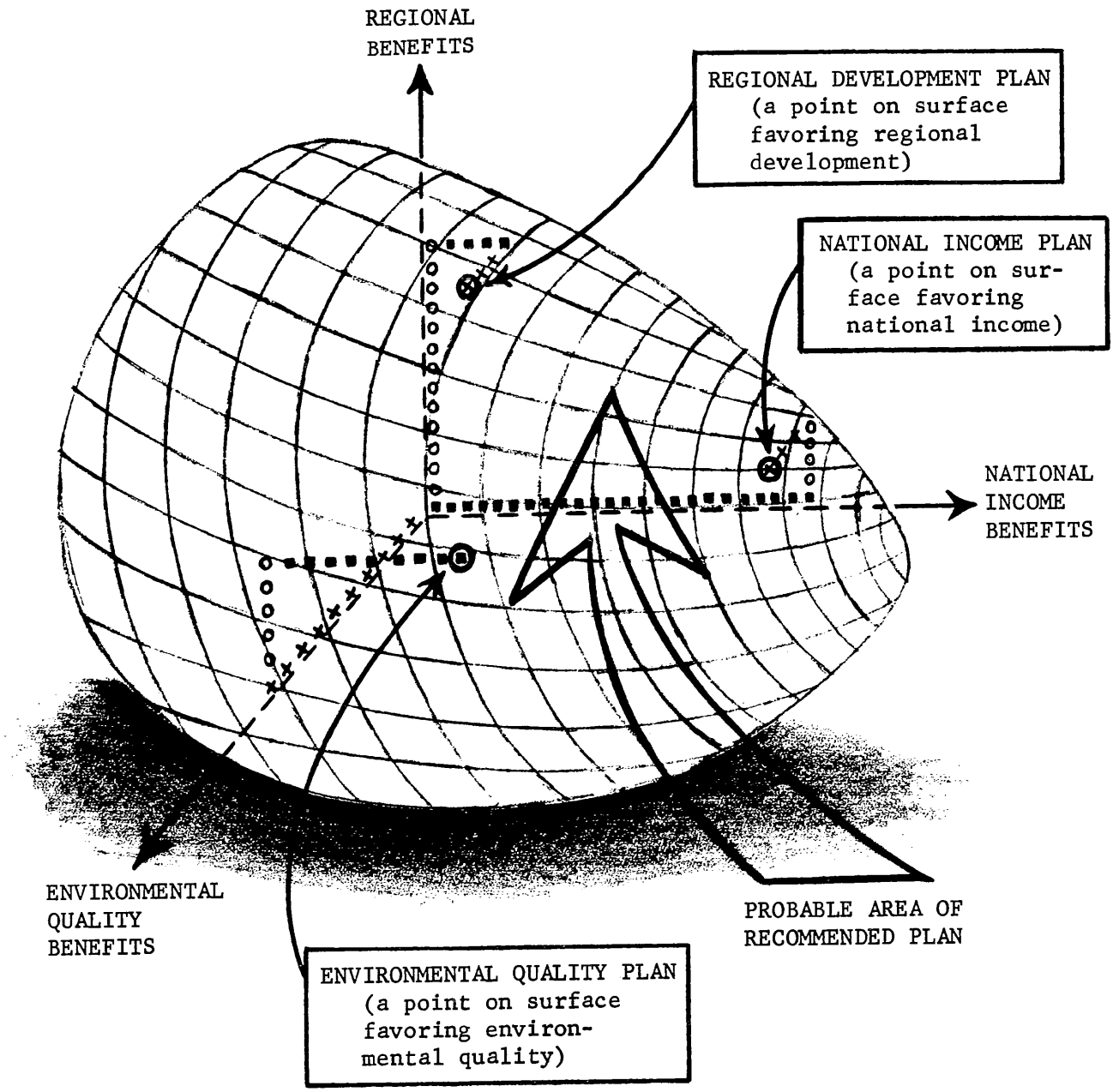
plans to recommend some combination of the three. An illustrative area for the recommended plan is shown on the diagram.

The above summary of the proposed rationale for planning is believed by the Study Group to represent the best conceptual basis for framework planning in the North Atlantic Region. The rationale is not meant as a blueprint that is to be reproduced exactly with empirical material and functional relationships, but rather as the viewpoint from which the various information available for framework planning can be ordered and analyzed. The relationship between the rationale and the framework plan can be compared to the relationship between the pure theory of benefit cost analysis and the very approximate applications of that theory in project design, with the difference that the framework plan deals with the general rather than the specific.

Further, it should be recalled that the task of the framework planners includes the collection of information, the discovery of gaps in available knowledge on water resources in the region, and the proposal of areas for further investigation. Thus the proposed rationale for plan formulation covers only part of the task of the Committee.

Finally, in evaluating the proposed rationale, a perspective on the relative importance of water resource development in the economic system as a whole is useful. The proposed rationale is based on the fact that every water resource investment affects a variety of social objectives, whether or not it is planned to attain only one objective. However, it is also true that a wide range of other public and private investment and non-investment trends and policies affect the same range of social objectives as water resources development. In some sub-regions of the planning area, investment in water resources development will be crucial to the attainment of certain objectives; in other sub-regions, it will not be so important in comparison with other trends and policies. The proposed rationale is therefore not intended to imply that investment in water resources development is providing controlling influences on the broad objectives of the planning, but rather that it is a contributing factor in attaining those objectives. As a result its effects on those objectives should be carefully investigated.

Attachment:
Diagram



THE GEOMETRY OF THE PROPOSED PLANNING RATIONALE

LEGEND:

■■■■■■■■■ National Income Components

ooooooooo Regional Development Components

xxxxxxxxx Environmental Quality Components

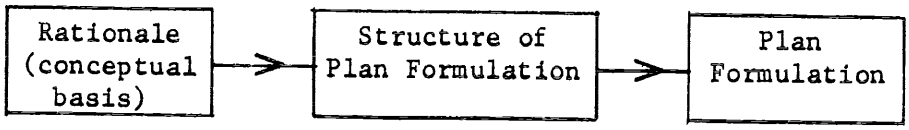
THE STRUCTURE OF PLAN FORMULATION

Remarks by Dr. David C. Major
North Atlantic Regional Water Resources Study Group
U.S. Army Corps of Engineers,
At The
Fifth Meeting of the Coordinating Committee,
North Atlantic Regional Water Resources Study
Brookline, Massachusetts
13-14 September 1967

THE STRUCTURE OF PLAN FORMULATION

In an earlier report, the proposed rationale for framework planning was summarized. The rationale provides the conceptual basis for planning for multiple objectives. The three proposed objectives are national income, regional development, and the quality of the environment.

In this report, a preliminary discussion of the structure of framework planning is presented. The purpose of this section is to relate the conceptual basis of planning to the types of information and output required in the formulation of a framework plan. The relationship between the topic discussed in this report, the rationale, and plan formulation is given by the diagram. This preliminary report is intended to serve as a basis for discussion at the fifth meeting of the Coordinating Committee.



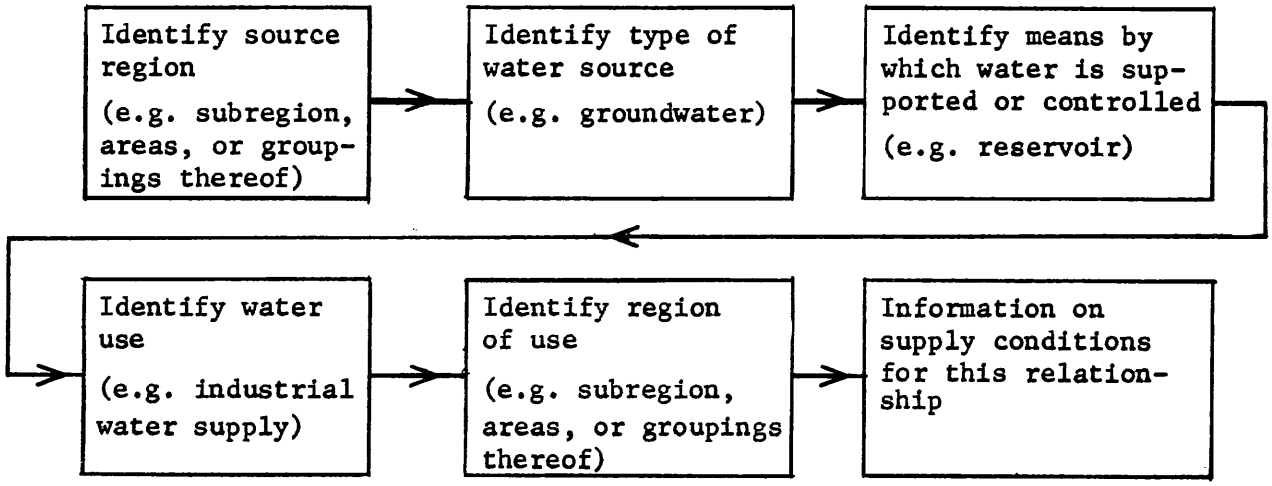
Converting the rationale into a structure for framework planning within which data and functional relationships at the framework level of generality can be incorporated is principally a matter of simplification. The set of data and functional relationships that would be required in a planning process approximating closely to the rationale would be highly complex and difficult to obtain. The required inputs for framework planning and the required outputs or recommendations are broad and generalized statements about water resource development problems. Thus, the conceptual basis of planning has to be explicitly related to this type of information.

The first broad simplification used in framework planning is that concern is focussed on the designated framework planning area. This is in accord with the guidelines for framework planning set up by the Water Resources Council. The second simplification is the breakdown of the broad planning area into subareas. The designation of these subareas is the key simplification made by the Study Group and the Coordinating Committee. The subareas used in planning are based on hydrologic considerations (except for the economic set of subregions) because common hydrology should provide areas that are relatively homogeneous with respect to water resource development. In actual plan formulation, the areas can be used either as presently designated or they can be further subdivided or combined. The choice depends on the characteristics of particular problems. Because of the generalized nature of the relationships used in framework planning, the original choice of subareas, and the skill with which subareas and groupings of the subareas are employed, will be important factors in determining the quality of the final plan recommendations.

The use of subareas is one of the principal sources of the advantages of framework planning over the more detailed project analysis that would characterize a planning process closely tied to the rationale. The use of subareas enables a broad-gauge plan covering a long time horizon to be formulated with limited staff. This provides a more useful view of the water resource development situation in a broad area than would be gained if the same planning effort were expended on more detailed analysis.

Given the primary simplification of subregionalization, the information required for framework planning falls into the two categories of information on supply conditions and information on demand conditions.

The nature of the information on supply conditions required for framework planning is illustrated in the diagram.

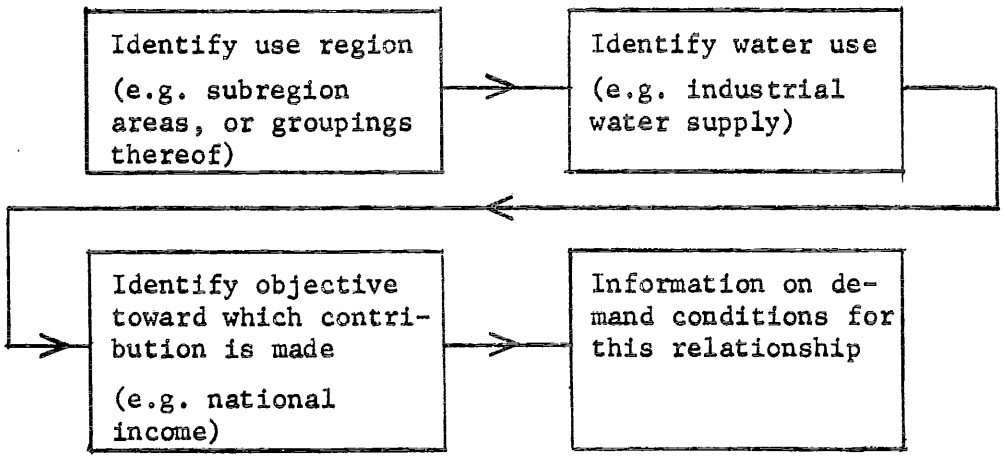


The purpose of the diagram is to provide a basis for the systematic review of the whole range of supply relationships in the framework planning area. In the diagram, it is indicated that in order to consider a supply relationship, a specific region that will be the source of supply must be selected. This might be one of the 21 designated subareas, or a combination or subdivision of subareas. Then, the type of water source must be identified. Broadly speaking, the type of source will be either ground water or surface water. For some supply relationships, however, atmospheric water or ocean water might be the source. Then, the means of controlling or supplying or affecting water from the specified source and region must be designated. Broadly, the means might be either structural or non-structural, with many types included within each of these categories. Next, the use to which the water is put must be considered. There are many possible use categories; the guidelines for the National Assessment list 16 water uses. Finally, the region in which the water is to be used in the specified manner must be identified.

Each of the items of information indicated in the diagram must be given in order for a supply relationship to be established. The planners must then attempt to develop whatever information is available and relevant about the relationship. Leaving for the moment the exact nature of the required information, it can be seen that there is a very large number of relationships that might be estimated even with no breakdown of the North Atlantic Region beyond the 21 subareas. With 21 source regions, 2 broad categories of water source, 2 broad categories of means, 16 use categories, and 21 use regions, there would be a total of 28,224 possible relationships if every region used water for each purpose derived from each source, by every means, from every region. This number would be an underestimate of the theoretically possible relationships, since the number of water sources, means, uses, and use and supply regions can be increased by defining categories more narrowly than has just been done.

However, many of the theoretically possible relationships will not be relevant to the framework plan. Relationships will be ruled out of consideration by hydrologic or geographical impossibility, or by costs so high that no serious consideration is required. In addition, not every means is appropriate to every source, and not every use is relevant to every region. Thus, the number of relationships for which information would ideally be developed is considered smaller than would be at first suggested by consideration of the diagram of supply relationships. Nevertheless, the diagram is important because it provides a basis for systematically considering all possible relationships. Many relationships can be discarded as irrelevant after the briefest consideration; but if all are considered at least once, planners can be sure that the relationships that are selected for careful study will include all of the relationships relevant to the framework plan.

The information sequence for demand relationships can be illustrated as in the diagram.



As with the diagram for supply conditions, the purpose of this diagram is to provide a basis for considering all possible demand relationships. In the diagram, it is indicated that in order to consider a demand relationship a specific region in which water use is to occur must be selected. Then, the type of water use must be specified. Finally, the objective to which the consumption of water in the specified manner in the given region is expected to contribute must be identified. With 21 use regions, 16 water uses, and 3 planning objectives, the total number of possible demand relationships is equal to 1008. However, the comments made about supply relationships apply here also. There will not be so many relationships of practical importance to plan formulation as there are possible relationships. Many water uses will not be relevant to many regions, and many uses in certain regions will not contribute significantly to each of the three objectives. Such irrelevant relationships can be omitted from further consideration after a brief review, and attention can be focussed on the demand relationships important for plan formulation.

An important part of developing information on demand relationships is the estimation of contributions of water use toward each of the objectives of planning.

In a plan closely tied to the planning rationale, national income and regional benefits would be precisely defined by economic theory. The measurement of these benefits would then require the application of detailed and difficult techniques. Environmental quality benefits could not be precisely defined, but they could be analyzed in a variety of decision frameworks in order to provide a ranking of various effects of water resource development on environmental quality.

At the level of framework planning, by contrast, broad and generalized measures of attainment of objectives are desired. The extent to which the national income objective might be attained through water use in a region can be measured approximately by first estimating water needs in the region. Then, the resource costs of meeting these needs can be estimated, and an approximate net measure of contribution to national income obtained by comparing needs and costs.

The extent to which the regional objective is achieved through water use can be estimated by considering the changes in regional output and income that will follow when water use in a region is increased. The potential movement of regional output and income should be considered not only for the amount of water use in a region that would be justified by national income considerations, but for larger amounts as well. Regional gains, like national income gains, should be put on a net basis.

To estimate the extent to which the environmental quality objective is achieved through water use in a specified region, available information should be analyzed and used as the basis for a rough ranking of the

merits and demerits of various effects of water use in the region. Effects on environmental quality should also be considered on a net basis.

A specified water use in a given region might affect each of the objectives, measured as above. For example, supplying water for industrial consumption in a given region might contribute positively to both the national income and regional objectives, but might have negative effects on environmental quality in that region.

Thus far, the exact type of information on individual supply and demand relationships required by framework planning has not been specified. In a plan closely tied to the rationale, a complex set of data and functional relationships would have to be developed. For a framework plan, more generalized functional relationships and less detailed data are required.

The exact type of information required about a supply or demand relationship will range from a statement of the magnitude or the direction of effects, through estimates of average numerical relationships, to estimates of functional relationships. For example, in evaluating the effect of a specified water use on environmental quality, only a statement of the positive or negative direction of the effect might be required. Or, a statement of magnitude would suffice for a cost relationship so high that it would not be relevant to practical problems of plan formulation.

For estimating the cost of supplying water for domestic use in a particular region, an average cost per million gallons per day might be appropriate to the needs of plan formulation. On the other hand, for estimating costs of providing water for industrial use to the same region, a function relating the cost of water to the amount supplied might be desirable.

The type of information required on each demand and supply relationship depends in important measure on the extent to which a relationship is affected by the other relationships in alternative plans. For example, a single estimate of average cost of supply for industrial water from a given source would not be adequate to planners' needs if the cost of supply that industrial water depended on whether other water uses were to be supplied from the same source. In such a case, the framework planners would have to estimate the cost of industrial water from the specified source under various assumptions about what other uses of the same water might reasonably be expected to occur in alternative plans. As another example, the benefits toward environmental quality from a given water use might depend on what other water uses occurred in a given region. In such a case, a statement of the direction of the effect of the given use on environmental quality would not suffice. An estimate of how the benefit changed with various combinations of water use in the region that might be expected to occur in alternative plans would be required.

What has been said thus far about information on demand and supply conditions has referred to planning with given economic, demographic, and technologic projections. In the many instances where alternative projections can be expected to influence plan formulation significantly, these alternative projections can be considered in terms of the previous discussion and diagrams. As an example, suppose that urbanization takes place not in one concentrated, extended area but rather in a number of smaller and somewhat separated areas. The planners would take account of this alternative assumption by reviewing demand and supply relationships to determine which relationships were affected by the change in assumptions, and to what degree. Another example would be a change in technologic assumptions, for example the development of cheap desalinization processes. In this case also the planner would review all of the relationships that would be affected by the change and attempt to estimate the general effects of the change on those relationships.

The structure for relating the framework plan to the proposed planning rationale presented here has been discussed in terms of required or desired information. However, an important practical consideration is that much of the desired information will not be available at all, or will not be available in a form adequate to the needs of framework planning. This problem is especially important in framework planning because the guidelines established for such planning emphasize that planning is to be based generally on available information rather than on newly developed information. The extent to which required information is not available will thus have a considerable effect on the results of plan formulation.

During the coming working period, planning effort should be concentrated on the development of information on supply and demand conditions, as well as on a concurrent elaboration of the structure suggested here. The material in this report is presented at this time to encourage discussion by members of the Committee on the problems of developing the desired supply and demand information.

The actual work of plan formulation can be undertaken only when available information has been developed and analyzed as fully as possible. Plan formulation includes the application to the data of various aids to decision-making to develop the three alternative plans illustrated in a diagram attached to the report "The Proposed Rationale for Plan Formulation." The decision methods appropriate to the work of plan formulation cannot be neatly set out in advance of a knowledge of what information on supply and demand conditions is available.

PLAN FORMULATION: RATIONALE, STRUCTURE AND PROCEDURES

by
Harry E. Schwarz & Dr. David Major
NAR Study Group, Corps of Engineers, North Atlantic Division

The subject of Dave Major's and my discussion today covers many parts grouped under the heading, Plan Formulation: Rationale, Structure, and Procedures. The purpose of this discussion will be to review what we already have done in relation to plan formulation, to explain a few new techniques, elicit your comments and set out for your review a set of working procedures to accomplish our common purposes.

This morning Dr. Major and I will share this presentation. I would like to ask you to defer discussions of the subject matter until after the second portion of our presentation after lunch when we can discuss plan formulation as a whole.

When we began our discussions on this subject we broke plan formulation into three sections: rationale, structure, and plan formulation itself. In developing the rationale we have agreed that we are planning not for rivers or for lands, but for people which populate these lands, which use these rivers.

Planning has meaning only when you plan for some specific objective and so we began our discussions two meetings ago by talking about possible objectives and came to the conclusion that while many objectives are possible, three are significant and sufficient to describe most of the possible mixtures of objectives for which we might have to plan. These three objectives, to refresh your memory, are: environmental quality, national efficiency, and regional development. All these are social objectives towards which the development of water and related land resources might contribute.

At Boston we described this system by showing a coordinate system with its three axes labeled with the three objectives and drew an egg-shaped surface to represent all the possible plans that could be developed. The coordinates of each point on this surface measured along the three axes being the amount of net benefits towards the objective. We then filled in this picture by talking about three possible illustrative examples each one emphasizing one of the objectives.

I'd like to remind you that when emphasizing one objective we do not forget that we must at least fulfill some portion of the other objectives. For instance, one illustrative example would be developed with an exaggerated concern for environmental quality. Even so there would be some development for the economic wellbeing included, though that might be incidental or the minimum acceptable. Similarly in the example emphasizing regional development some consideration must be given to national efficiency and to environmental quality. It is the purpose of these examples to illustrate the choices without polarizing them to such an extreme that no area of compromise can be perceived. Exaggerating

the concern for one objective in each example but not completely forgetting the others will, I believe, make the choices explicit and still allow for the development of mixed objective plans from the examples. At the last meeting it was suggested that the probable plan developed by the committee as its recommendation would lie somewhere between the examples developed with emphasis on single objectives, or in other words with a plan developed for a mix of objectives which may vary from area to area, from time horizon to time horizon.

Let us next consider the structure of plan formulation. Under structure I mean the outline method which we will use to determine either one of the examples developed to illustrate one objective or the final plan for a mixed objective. This structure consists of three components and planning is done by relating these three components to each other. These components are: The needs, the resources and the devices.

Needs are the various purposes for which we plan, like water supply, flood control, navigation or esthetic enjoyment. Resources are the raw materials with which we deal, like water under the ground, water on the ground and water in the clouds. Devices let us call all those things which we can use to change either a resource to fill a demand or a demand so that it can be fulfilled by the existing resource. Those devices which change or manage the resource itself we have called active devices and those which change a demand, passive ones. Reservoirs, levees, pipelines, wells are examples of active devices. Zoning, legislation, pricing policy are examples of passive ones. In other words devices have an output which fulfills all or some of the needs. We could draw a figure showing the interrelations of all the needs, resources and devices and a mathematician would call it a three-dimensional matrix where the lines are the needs and the columns the resources and the devices.

Figure 1 indicates a simplified version of the actual work chart that has been developed to show the relationships of needs, resources and devices. Along the left five water needs are shown. As column headings there are three different resources and four different devices. A line can be drawn from one of the needs which will intersect with any of the three resources. From each of the resources intersections, other lines can be extended to meet any of the devices. Therefore, in the right section of this chart there is a unique point for each possible combination of needs, resources and devices. With five needs, three resources and four devices there are 60 such points.

The filled-in squares represent all those points where the output from a device acting on a resource can fulfill a need. Areas where no such significant relationship occurs have been left blank. For instance, on the first line which is all black we have concluded that for the water withdrawal need and surface water as the resource, all devices listed have significance. While for instance on the fifth line that is instream water need and subsurface water as the resource, none of the devices are especially significant. Figure 2 represents our actual working chart and indicates to a degree the complexity of the real problem.

There are 15 needs, 9 resources and 30 devices listed here and this means 4050 different points of intersection.

In our preliminary analysis of these we have concluded that there are 655 or about 16% which have significance in our planning. These still are too many relationships to analyze in any kind of detail and we are now hard at work to reduce their number by selecting those most important and to eliminate those which while existing will not greatly influence the decisions in framework planning.

This method of analysis might seem overly complicated and cumbersome to you but it has one great advantage. It forces us, the planners, to make our choices explicit and allow you, the reviewer, to evaluate our judgment. We have prepared copies of this chart for distribution and you can pick one up at the end of this session. If you have any ideas on significant relationships which we have forgotten or insignificant one we have marked, please indicate them on your copy of the chart and mail it back to me within the next two weeks.

Now what are these relations which we want to determine for each of these points of intersection. They are numerical or descriptive information which we have on the specific needs, specific resources and specific devices, their costs or benefits, their output, their beneficial and adverse effects.

For any one need for instance, this material must show the time and place at which some output must fill it, the quantity of resources needed and the quality of those resources. The data on Fish and Wildlife for instance which you have heard discussed at this meeting, is an example of portions of the needs information.

Resource information similarly must show when and where the resource is available and what possibilities there are for its management. Mr. Cederstrom's presentation on groundwater availability in hard rock aquifers is an example of this type of material. And finally, we need an analysis of the effectiveness and cost of devices and there you heard from Mr. Ignazio and his analysis of one of the devices, generalized costs of reservoirs in the region.

So you can see that a block of information is being developed for each need, for each resource, and for each device and we will hopefully be able next winter to formulate plans by being able to draw from this information to evaluate the use of the output from any one device on any one resource for any one need which is significant to the decision making process.

Next Dr. Major will discuss a technique which we hope to utilize in the analysis of one very important part of the output and benefit relations - those concerning industrial water supply.

In the process of plan formulation we are searching continually for techniques that will enable us to generate information of importance to us. One such technique, which we will review now, is a modification of the national input-output model that yields a regional input-output model for estimating industrial, agricultural, and commercial water use. This model has been developed by a group working at the University of California at Berkeley.

To demonstrate the usefulness of this model, we will review briefly the nature of input-output in general, the conversion of the national matrix to a regional matrix, and the purposes to which this technique can be devoted.

Input-output is a simplified method for picturing the interactions of an economy broken down into producing sectors. Although the underlying production theory is very simple (inputs are assumed to be proportional to outputs), the construction of a table is ordinarily very expensive and time consuming. For example, we were told some time ago that the direct construction of a table for the NAR might cost several millions of dollars and take several years. The method that we will discuss today represents a considerable scaling down of that estimate.

For the United States as a whole the input-output table currently available is for the year 1958. This table has 81 sectors. A new table is being prepared by the government for the year 1963. This table should have about 350 sectors, a great increase in detail. (Something of the nature of the detail is illustrated by the fact that a preliminary breakdown of sectors recently made available showed as separate industries: tanks and tank parts, and morticians goods).

We have with us the input-output table published by Scientific American for a hypothetical gross national product of 750 billion dollars at 1958 prices. The interindustry relations in this table are based on the 1958 table. As a matter of fact, the GNP in 1967 exceeded 750 billion dollars at 1958 prices so that this is a picture of a table that is somewhat outdated both as to totals and as to interindustry relationships. The table gives a picture of the flows in the economy from one sector to another, as well as a picture of the gross national product accounting scheme.

One can focus on several important parts of the table. The first is the large interindustry flow matrix which shows all flows from one industry to another in dollar terms and in coefficients that will be explained in a moment. Each small box (including the small colored boxes) represents transactions from one supply industry, as supplier, to one industry, as user. A group of columns to the right is the final demand group (that is, the sectors that compose GNP on the output side); a group of rows on the bottom is the value added group (that is, payments to factors of production and certain other payments; these payments add up to the gross national product on the income account). Furthest to the right is a single column which indicates the gross output of every industry;

namely, the sum of outputs to other industries and to final demand. The key differences between the information available on this table and in the GNP accounts are, first, the existence of the interindustry sector, and, second, the gross output column.

Figure 3 depicts two of the small interindustry boxes in order to show more clearly the information available in the interindustry matrix. The small numbers on the outside of the boxes refer to the numbers of the industries in question in the input-output scheme. Number eight is the food industry, number 60 is chemicals, and number 40 is primary iron and steel. In the figure, the iron and steel industry is the supplying industry, and food and chemicals are the user industries. Steel, of course, is also a supply industry to the steel industry; however we have not shown this box. (In the complete table every industry is shown as a supplier and as a user). The largest of the three figures in each box represents millions of dollars in flows from the supplier to the user. This is the number of millions of dollars of output of the steel industry bought by the food industry and the chemical industry for a hypothetical GNP of $750 billion. The small figures in the left hand corner of the boxes represent the number of dollars spent on the input of the supplying industry per thousand dollars of user industry gross output. In other words, if the user industry spent 1% of its total revenue on the supplying industry, it would be spending $10 per thousand; the figure in the lower left hand corner would then be 10. It is conventional in such tables to color in a box that represents more than 1 percent of direct input.

The small figure in the lower right hand corner of each box represents one of the most remarkable aspects of input-output economics. This figure represents the total amount of the supply industry's production which is required to produce $1 in final demand output of the user industry. This figure is in cents per dollar. As a percent, it's always at least equal to and generally greater than the figure in the lower left hand box. The food industry, for example, uses little steel and iron as a direct input, but the other industries supplying to the food industry use iron and steel in producing their own outputs. All of this steel is indirectly required to produce an additional dollars' worth of food for final demand, and it is included in the coefficient on the right in addition to the steel and iron used directly by the food industry. This coefficient is called the "inverse" coefficient after its mathematical significance. This coefficient has important uses: for example; in a war time planning situation one could estimate directly from this coefficient the amounts of steel required to produce, say, 100 airplanes. By examining all of the inverse coefficients in the table one can estimate the total of all commodities that would be required to produce a certain bill of final demand, that is, a certain GNP. It is this use that is relevant to our planning efforts.

This then is a brief description of the national input-output table. Next we consider how we can use this table for framework planning. To produce a regional flow table from the national table, information on regional final demand and gross output must be developed. This is applied

to the national table in a computer program developed at Berkeley; and the result is a table of regional industrial flows. This method of deriving a regional table should be reasonably free of gross errors if the region in question is sufficiently similar to the national economy. This is true of the NAR, in which a large fraction of GNP is produced. When the regional industrial flow table has been generated, water use coefficients can be substituted for the industrial flow coefficients by a simple process of multiplication. If we know that an industry uses on the average a certain number of acre-feet of water per million dollars of output, we can apply this figure to the industrial coefficients in the regional input-output table to derive water flow coefficients. One further modification of the table is entailed in this process. Since good water use coefficients are not available for all industries at the level of disaggregation shown in the table, the sectors of the table are aggregated as required.

As a final result of these operations, we have a regional input-output table expressed entirely in terms of water use coefficients. With this table, one can estimate the total water use required to increase the output of any industry to final demand; more important, one can estimate the entire gross water demand in the NAR of industry, commerce, and agriculture implied by any bill of final demand.

This is a remarkable result, for it permits rapid calculation of gross water needs on the basis of alternative assumptions about regional demand; given the assumptions of the regional input-output table, moreover, the calculations of gross water needs for each sector are consistent with each other.

We expect to use the input-output technique to gain insight into the water planning problem for the NAR in several ways. First, as just mentioned, the table will enable us to experiment quickly with the water requirements not only of the OBE guideline projections; but for other GNP projections as well. Second, since emphasis on alternative objectives should imply different compositions of regional final demand we should be able to explore water demands for different objective mixes. Finally, by varying the water coefficients, we can explore the effects on gross water demands of changing technology.

There are some extensions of this method that may prove fruitful. One is the application of the national-regional conversion method to produce tables for each of the six major NAR planning regions. A second is the application of linear programming to the table, assuming water as a constraint, to derive an implied value for an acre-foot of water in the region.

The use of this input-output method in the NAR has a number of significant limitations. First, the water demands that can be calculated are limited to the gross demands of industry, agriculture, and commerce. The model does not yield estimates of household demand, true municipal demand, or demand for water in place (recreation) or for the restraint of water (flood control). In addition, the method suffers from fixed

coefficients, from outdated coefficients, from the application of water use coefficients that may not apply accurately to the interindustry coefficients of a table produced in an earlier year, and from the inaccuracies resulting from the conversion of the national table into a regional table.

In using this tool we will always have to be aware of these limitations, in order to avoid imputing more validity to the results of applying the method than these results warrant. All things considered, however, we think that the use of the input-output table for regional water demand estimation will yield results whose benefits significantly exceed the costs of adapting the national table to the NAR.

Next in our discussion of Plan Formulation: Objectives, Structure, and Procedures, we wish to relate in a preliminary way our planning structure of outputs, sources, and devices to the planning objectives. The necessity of relating the elements of the planning structure to the planning objectives is grounded in the fundamental problem of planning, mapping out the net benefit transformation surface, and the approach to planning adopted by the Coordinating Committee, developing three alternative combinations of net benefits as a preliminary to selecting the NAR framework plan.

To recall, the net-benefit transformation surface, the egg-shaped surface discussed previously and referred to by Mr. Schwarz this morning, is a conceptual presentation of all possible combinations of net benefits attainable through water resource development in the NAR. The basic difficulty with planning is that this surface is hard to discover, an observation that applies equally well to a surface appropriate to family expenditure patterns and to framework plans for water resource development. In order to deal with this difficulty, the approach that has been adopted is to develop three illustrative net benefit combinations (or points on the surface), each representing what we have called an exaggerated concern for one or the other of the planning objectives. With the information presented on each of these three net benefit combinations, the Coordinating Committee should have a good basis for deciding on a framework plan.

In order to develop and present these alternative combinations of net benefits, we have to specify methods of measuring movement along each of the axes representing net benefits for the planning objectives, and then to specify the distance quantitatively or qualitatively, along each axis between each combination of net benefits. It is this information that will enable the Coordinating Committee to judge the alternative opportunities available through water resource investment in the NAR.

The sources of information for developing these measures, and settling on three alternative net benefit combinations, are material developed by the cooperating agencies in the framework plan, by the Study Group, and by other offices and agencies, both public and private. A considerable expenditure of effort will be needed to coordinate this information, to insure that the basis of analysis in each case is comparable; and to avoid what our consultants referred to as a plan composed of a collection of appendices.

We should note that, could we know the entire transformation surface, we would be interested in the marginal relationships about the three alternative net benefit combinations that we will develop. These are the key to the exact welfare optimum in planning. We will not have these, although we may have information about the areas around the three selected points that the Coordinating Committee will find of interest.

The selection of the three alternative net benefit combinations intended to provide a basis for Coordinating Committee decision-making is a matter of technical judgment, with the criterion the extent to which each alternative can be expected to assist the Coordinating Committee with its choice of a plan. The selection also depends, of course, on available information.

We want now to approach the problems of measurement along the axes, and selecting and differentiating between three alternative net benefit combinations, by bringing out the extent of the relationships between the elements of the planning structure (outputs, sources, and devices) and the planning objectives. We begin with the relationships between system outputs and the objectives.

System outputs are related directly to the quality of the environment. While all outputs can be expected to have some effects, beneficial or adverse, on the quality of the environment, certain types of relationships will be more important than others. Since work on these relationships is in the pioneering stage today, our own efforts must include a certain amount of conceptual work if we are to focus effectively on the important variables. Although we hope to develop ways of describing environmental quality benefits, we do not expect to measure them in money terms.

It is important to note that the calculation of environmental quality effects from system outputs does not necessarily depend in any simple way on market processes. An example of an environmental quality effect not reflected in market phenomena is the use of domestic water supply for gardens and lawns. This use benefits not only the user (who, in theory, pays a market-oriented price), but also other persons in the vicinity, because of the increase in their environmental quality through the use of domestic water by the purchaser to improve his own grounds. A net benefit combination emphasizing environmental quality would, by this reasoning, provide for greater supplies of domestic water than a purely market-oriented net benefit-combination.

This is an appropriate point at which to mention two sources of information on which we intend to draw in considering the relationships between system outputs (and sources and devices) and environmental quality. The first is the interesting and insightful study performed by Professor Zube and his colleagues at the University of Massachusetts on the visual and cultural environment of the NAR.

This study, available in draft to the members of the Coordinating Committee and others interested, provides us with valuable information particularly on the open areas of the NAR.

The second general source of information on which we will draw is a study on which the Study Group is embarking that will involve contact with persons dealing with water resources, parks, street cleaning, and the like in New York City, in order to develop information on the environmental quality effect of system outputs in the urban context. This study, of course, is intended to provide information about urban areas in the NAR in general, not in New York City alone.

We have more information on the relationships between system outputs and national income than on the relationships between system outputs and any other planning objective, for the reason that increases in the national income have been the principal focus of benefit-cost analysis in the past. We intend to rely principally on the techniques already developed for relating system outputs to national income gains and losses. Because the conceptual framework for relating system outputs to national income is well developed, and because many applications have been made in this area, our efforts will be devoted primarily to an application of standard methods. We hope to develop the relationship between system outputs and regional income or development gains by considering the extent to which different industries in different regions might react to greater than efficiency levels of system outputs. The theory of regional growth is not well developed, so that approximation will be required in this regard. We will perhaps be able to borrow from the techniques developed by the Appalachia planners in considering regional benefits to that area. In addition to the problem of relating system outputs to regional income or development gains, there is the problem of specifying in detail the regional objective for which a net benefit-combination is to be constructed. Some possible objectives are the development of the region as a whole beyond the efficiency level; the development of only the poorer areas within the NAR, or the development of each subregion to a specified extent. Our approach here will be to provide information on several variants sufficient to enable the Committee to select the most desirable regional objective.

Sources have also to be analyzed with respect to the objective of planning. It can be seen that sources are directly related to the objective of environmental quality, and we have information in the Zube study referred to previously that will help us in depicting these relationships. Sources are related in a straightforward manner to the efficiency objective, for which only least cost is relevant. Sources are also directly related to regional objectives, since certain sources can be developed (and thus investment undertaken) only in certain areas.

Finally, devices are also related to each of our planning objectives. Devices are clearly related to environmental quality considerations; for example, the Zube report refers to types of landscapes in which certain control devices might make a positive contribution to environmental quality from the visual standpoint. The efficiency objective is indifferent to devices except with respect to cost; the material presented

at this meeting by Mr. Ignazio is an example of one relationship between devices and the efficiency objective. Regional objectives are related to devices since some devices can be utilized, and this investment undertaken, in certain regions and not in others.

To sum up our position: we have developed preliminary relationships between outputs, sources, and devices in the NAR; and we are proceeding to map out the relationships between each of these and our planning objectives, in order to be able to develop net benefit combinations that will assist in the choice of framework plan, and to be able to describe effectively the differences in terms of net benefits among the alternatives to be developed.

ANALYSIS OF RELATIONS BETWEEN NEEDS, RESOURCES, AND DEVICES

MAY 1968

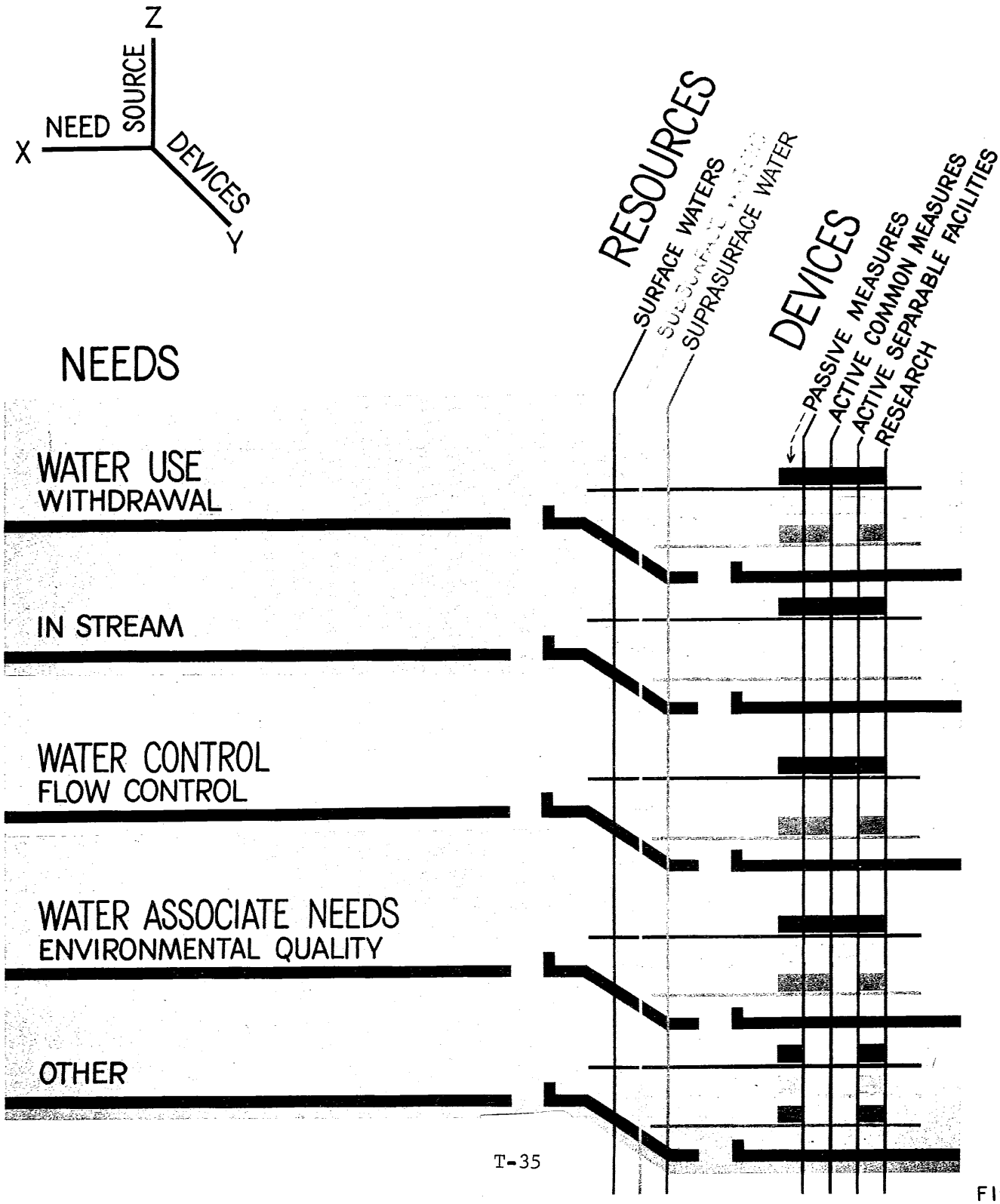
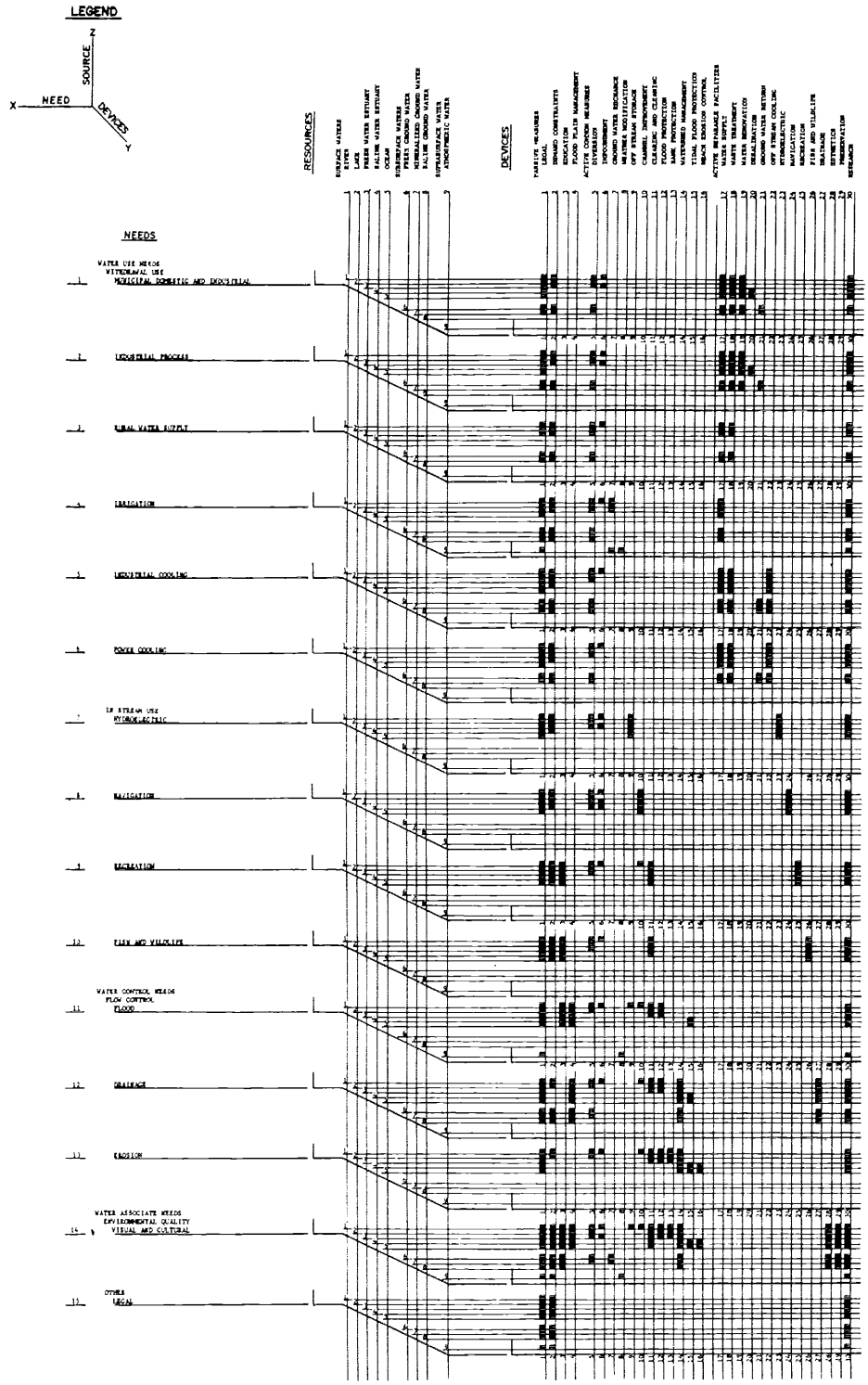


FIGURE 1



NORTH ATLANTIC REGIONAL WATER RESOURCES STUDY

ANALYSIS OF RELATIONS BETWEEN
NEEDS, RESOURCES, AND DEVICES

May 1968

FIGURE 2

NAR Study Group, NAD
U.S. Army Corps of Engineers

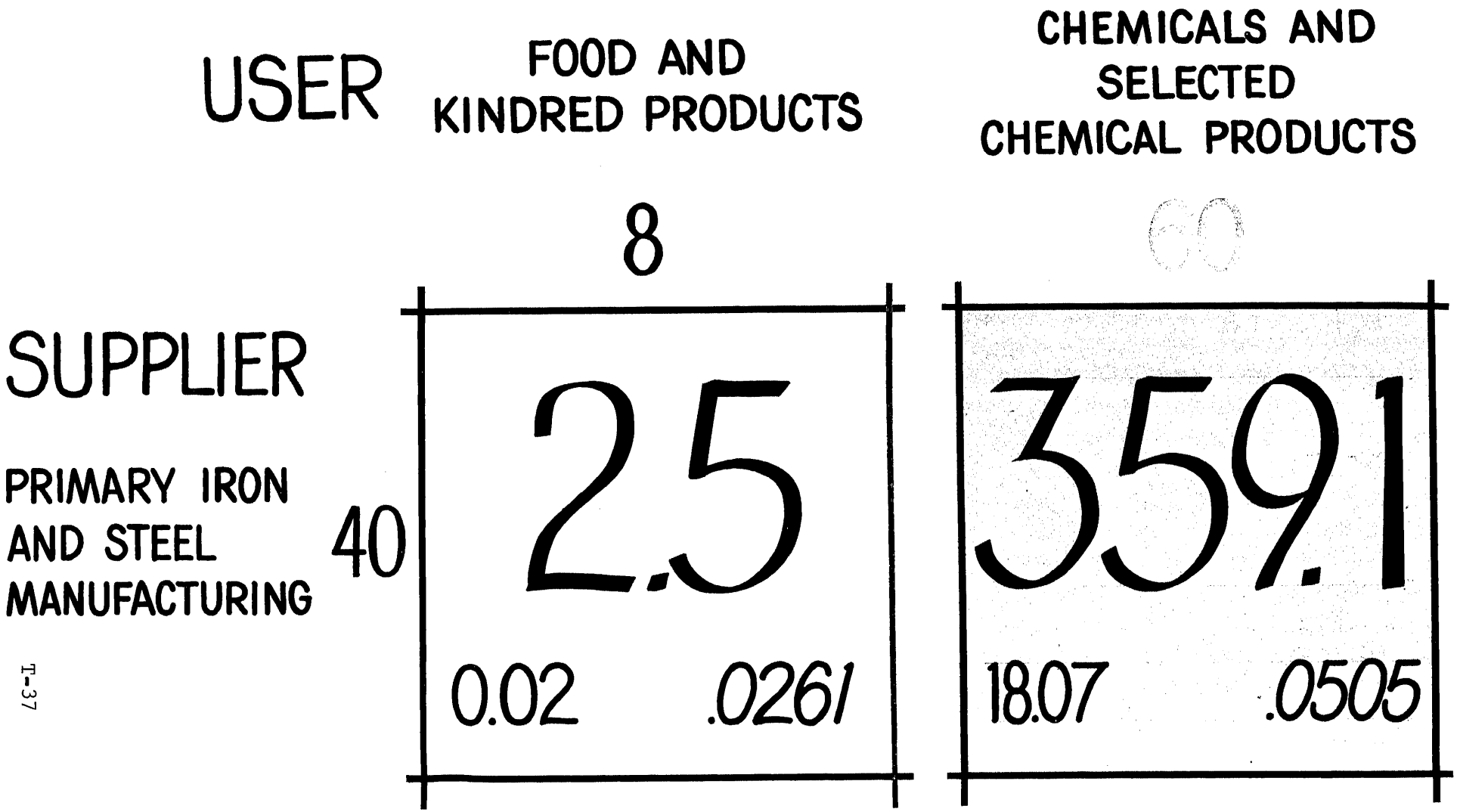
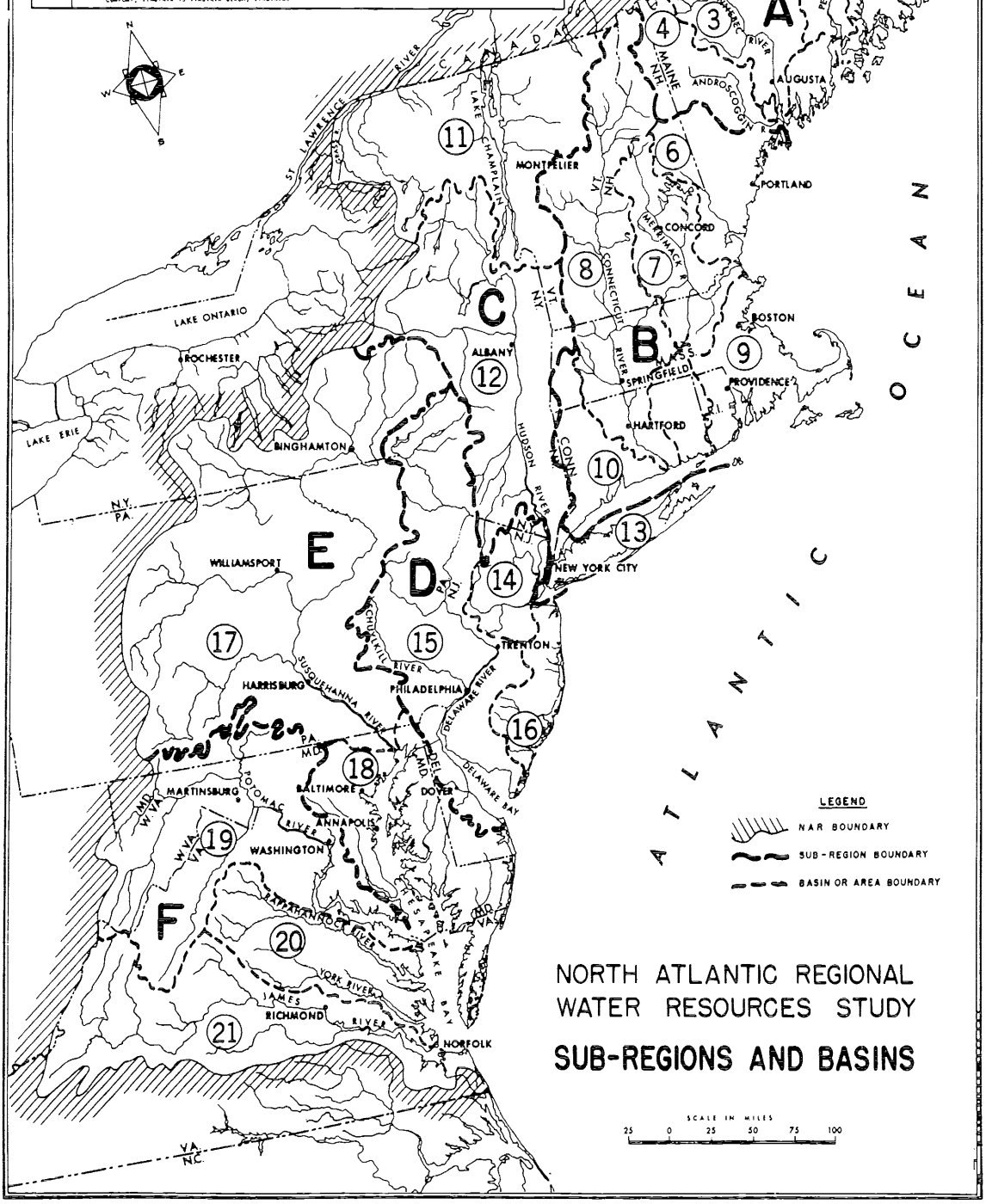

USER
FOOD AND KINDRED PRODUCTS
CHEMICALS AND SELECTED CHEMICAL PRODUCTS
SUPPLIER
PRIMARY IRON AND STEEL MANUFACTURING
8
40
2.5
0.02
.0261
359.1
18.07
.0505

FIGURE 3

SUB-REGION	BASIN OR AREA
A	1. ST. JOHN RIVER, MAINE. 2. PENOBSCOT RIVER, MAINE. 3. KENNEBEC RIVER, MAINE. 4. ANDROSCOGGIN RIVER, MAINE AND NEW HAMPSHIRE. 5. ST. CROIX RIVER, MAINE; AND ATLANTIC COASTAL AREA FROM THE INTERNATIONAL BOUNDARY TO CAPE SMALL, MAINE.
B	6. PRESUMPSCOT RIVER, MAINE; SACO RIVER, MAINE AND NEW HAMPSHIRE; PISCATAQUA RIVER, NEW HAMPSHIRE AND MAINE; AND ATLANTIC COASTAL AREA FROM CAPE SMALL, MAINE TO NEW HAMPSHIRE-MASSACHUSETTS STATE LINE. 7. MERRIMACK RIVER, NEW HAMPSHIRE AND MASSACHUSETTS. 8. CONNECTICUT RIVER, VERMONT, NEW HAMPSHIRE, MASSACHUSETTS AND CONNECTICUT. 9. NARRAGANSETT BAY DRAINAGE, MASSACHUSETTS AND RHODE ISLAND; PAWCATUCK RIVER, RHODE ISLAND AND CONNECTICUT; AND ATLANTIC COASTAL AREA FROM NEW HAMPSHIRE-MASSACHUSETTS STATE LINE TO RHODE ISLAND-CONNECTICUT STATE LINE. 10. THAMES RIVER, CONNECTICUT, MASSACHUSETTS AND RHODE ISLAND; HOUSATONIC RIVER, CONNECTICUT, MASSACHUSETTS AND NEW YORK; AND CONNECTICUT COASTAL AREA.
C	11. ST. LAWRENCE RIVER, NEW YORK; AND LAKE CHAMPLAIN, VERMONT AND NEW YORK. 12. HUDSON RIVER, NEW YORK, VERMONT AND MASSACHUSETTS. 13. NEW YORK CITY, LONG ISLAND; AND WESTCHESTER COUNTY COASTAL AREA.
D	14. PASSAIC RIVER, NEW JERSEY AND NEW YORK; RARITAN RIVER, NEW JERSEY; AND OTHER NORTHERN NEW JERSEY STREAMS. 15. DELAWARE RIVER AND DELAWARE BAY, NEW YORK, NEW JERSEY, PENNSYLVANIA AND DELAWARE. 16. ATLANTIC COASTAL AREA FROM SANDY HOOK, NEW JERSEY TO CAPE MAY, NEW JERSEY.
E	17. SUSQUEHANNA RIVER, NEW YORK, PENNSYLVANIA AND MARYLAND. 18. PATUXENT RIVER, MARYLAND; NANTICOKE RIVER, MARYLAND AND DELAWARE; DELMARVA PENINSULA FROM CAPE HENLOPEN, DELAWARE TO CAPE CHARLES, VIRGINIA; AND CHESAPEAKE BAY DRAINAGE FROM CAPE CHARLES, VIRGINIA TO POINT LOOKOUT, MARYLAND.
F	19. POTOMAC RIVER, MARYLAND, VIRGINIA, WEST VIRGINIA, PENNSYLVANIA AND DISTRICT OF COLUMBIA. 20. RAPPAHANNOCK RIVER, VIRGINIA; YORK RIVER, VIRGINIA; AND CHESAPEAKE BAY DRAINAGE FROM SMITH POINT, VIRGINIA TO OLD POINT COMFORT, VIRGINIA. 21. JAMES RIVER, VIRGINIA AND WEST VIRGINIA; AND CHESAPEAKE BAY AND ATLANTIC COASTAL DRAINAGE FROM OLD POINT COMFORT, VIRGINIA TO VIRGINIA BEACH, VIRGINIA.



NORTH ATLANTIC REGIONAL WATER RESOURCES STUDY

SUB-REGIONS AND BASINS

FEBRUARY 1967

CHAPTER 3

FIRST STAGE OF PLAN FORMULATION

DEPARTMENT OF THE ARMY
NORTH ATLANTIC DIVISION, CORPS OF ENGINEERS
90 CHURCH STREET
NEW YORK, N. Y. 10007

IN REPLY REFER TO

23 May 1969

MEMORANDUM 69-28
TO MEMBERS OF THE COORDINATING COMMITTEE
NORTH ATLANTIC REGIONAL WATER RESOURCES STUDY

At previous Coordinating Committee meetings, an effort has been made to present summaries of what had been accomplished during the preceding months, and to present proposals and suggestions for work to be accomplished during the months ahead, seeking the Coordinating Committee's guidance on this matter. The preceding months of this meeting have been spent on the initial phase of plan formulation and with this memorandum the report covering this activity is transmitted.

The report is arranged in three parts. Part I contains short explanations of the methodologies used by the various agencies in developing their material. Part II is a reportage of the highlights of the meetings of the Plan Formulation Work Group containing both general observations and summary tables listing demands and suggested devices by basins and objectives. Part III includes interpretations of the material presented at the plan formulation meetings; specifically, tables showing (1) balances between available, developable and requested water, (2) some discussion of the special opportunities towards each objective for each basin and (3) an overall summary.

This first mailing contains the general sections of the report, and sections covering basins 9, 12, 13 and 14. These basins were given priority as they are among the most complicated within the region. The remaining basin sections will be sent as they are completed.

The material generated by the first round of plan formulation is to serve as the basis for delineation of the options in water resource development available to the Coordinating Committee in the North Atlantic Region at the framework level. The principal outcomes of the first round of plan formulation have been: the generation of demand estimates for the demands as listed in our study; cost estimates for a limited number of devices; the gradual development of agency methodologies adapted to multiple objective projections; and the development of a plan formulation work group gradually more accustomed to working in the multiple objective framework. The methodologies and summaries of presentations and discussions at the first round plan formulation meetings have been included as part of the inclosed report. Perhaps the most striking aspect of these summaries and methodologies is that even during the first round significant differences emerged between the possible programs toward each of the varying objectives. This has occured despite the limitations of working with one set of economic base projections and the necessity to adapt existing agency methodologies to multiple objectives.

It is important to remember that numerical material must be considered as a first estimate, indicating the general magnitude only, regardless of the apparent accuracy. Certain important parts of the NAR Study were treated only lightly in this phase because of time, personnel and fund limitations. The one most important part of this type is the consideration of coastal and estuarine problems, a shortcoming we hope to eliminate during the coming year.

The next step in plan formulation would appear to be: (1) improved estimation of demands, broad benefits and costs toward each objective; (2) delineation of the economic, demographic and hydrologic interrelations between different demands and between different basins, and (3) the initial integration of preferences as to objectives for each region expressed by the Coordinating Committee into plan formulation.

It was thought that a useful way to generate discussion on these steps and on the alternatives was to discuss for each basin the opportunities that seemed to be most relevant toward each objective, on the basis of material brought out during the first phase plan formulation meetings. This was done with the assistance of the Planning Associates at the Board of Engineers for Rivers and Harbors, and with the assistance of Professor Zube of the University of Massachusetts. The criteria used in selecting demands and devices that appeared most relevant for each objective were undoubtedly criteria that in part reflected single-objective planning experience.

The purposes of the discussions of opportunities toward objectives in each area are to stimulate discussion on the priorities of demand related to objectives; to stimulate comments on possible methods and criteria for broad gauge benefit measurement; and to stimulate discussion of devices, demands or objectives that appear to warrant particular effort in certain basins, without of course ignoring other devices, demands, or objectives in those basins. In effect, the sketches for each area are indications of some of the work that is intended for the next planning period.

The next step is up to you. At the joint meeting of the Coordinating Committee and the Board of Consultants you will have the opportunity to discuss the process and the specifics of plan formulation with the Board of Consultants, with the members of the technical staffs and, most important, with your fellow Coordinating Committee members. This discussion, along with your preliminary review of the material sent and the detailed review following the Coordinating Committee meeting, should give you the basis for giving guidance to the plan formulation effort in its second phase. This guidance should include: (1) corrections of fact or interpretation, (2) your views setting priorities between demands or levels of

demands for each objective, (3) your desired level of development or type of development by area and (4) an indication of your trade off values between objectives expressed either directly or by reference to demands that you would suggest at this time should circumstances make choices necessary.

To make this information useful it should be received by this office not later than the 25th of July for areas 9, 12, 13 and 14, and not later than the 8th of August for the remainder of the areas.

I hope that you will be able to at least review the general discussions, methodologies and the first of the basin summaries before the meeting. This would make the discussions at the meeting most fruitful and exploit the knowledge of our consultants to the utmost.

HARRY E. SCHWARZ
Executive Secretary

NORTH ATLANTIC REGIONAL WATER RESOURCES STUDY

FIRST REPORT ON PLAN FORMULATION

Prepared By
The NAR Staff and Plan Formulation Work Group

May 1969

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ABSTRACT

This first report summarizes the activities of the first phase of plan formulation. It reports and interprets first estimates of the needs and of the devices to fulfill the needs based on the best judgement that can be assembled at this time. The material should give a good overall picture for guidance of the second phase of plan formulation.

This report is organized into three parts. The first contains short summaries of the methodologies used by the various cooperating agencies to arrive at their first estimates. The second part contains a summary of the discussions at the plan formulation meetings, and the third part some interpretations of the estimates furnished and of the results of the discussions.

PART II

SUMMARY OF PLAN FORMULATION MEETINGS

a. General Discussion

1. The Plan Formulation Work Group met for a total of 27 days. Meetings were conducted at Boston, Mass., (basins 1-10, 10 days); at Albany, N.Y., (basins 11-13, 4 days); at Philadelphia, Pa., (basins 14-16, 4 days); at Harrisburg, Pa., (basins 17, 18, 3 days); at Washington, D. C., (basins 19-21, 3 days); and at New York, N.Y., (reviewing of all basins, 3 days). Staff members from participating Federal agencies, from most of the states concerned in each basin, and from several local and regional agencies, participated in these meetings. Mr. Harry E. Schwarz and Dr. David C. Major alternately chaired the meetings. For every basin, each objective and each need was discussed in turn. The function of the chairman, in addition to the traditional ones, was to stimulate discussion, to insure that opposing viewpoints and alternative proposals were brought out and to summarize as succinctly as possible the material discussed. The meetings turned out to be more than sessions in which data and ideas were brought out. They became a learning process, with each succeeding meeting being a little better and resulting in greater understanding between the various members. Thus, in addition to their providing the empirical material and concepts, these meetings served to cross-educate the work group members, make them sensitive to the problems of other members and make everyone better prepared for the more rigorous plan formulation steps to come.

2. This section of the report, Part II, deals only with the immediate results of the meetings as they pertain to the first phase of plan formulation. Specific estimates presented for each basin will be summarized later in this report. This part of the report presents only the material which is generally applicable to the first plan formulation effort as a whole.

3. All appraisals needs must be considered as broad estimates only. These estimates cover large geographic areas with a degree of sensitivity relevant to the decisions that will be made in a framework study. The needs or demand estimates should only be considered as appropriate for the whole area for which they are presented; they are not intended to serve as the basis for disaggregation to smaller areas. Similarly, small area estimates, developed as intermediate figures under some of the methodologies, should not be used in any disaggregated manner.

4. Needs or demand estimates vary from objective to objective. Discussions and the progressive experience at the meetings clearly showed the validity and importance of these differences based on separate objectives. Difficulties, however, exist in deriving numerical values for these needs or

demands based on multiple objectives. These problems are caused, in part, by the newness of this approach and also by the population and economic projections that are geared to a single trend representing an undefined mixture of objectives.

5. Four of the needs showed strong variations between objectives. Power cooling was one of them and the discussions brought out that here the differences between objectives resulted from shifts of the location of power plants between basins and from technological differences, such as balancing greater transmission costs against savings from locating in areas not requiring further investment in water resources to support power production. Similar large differences developed (1) for visual and cultural needs due to various levels of development for this purpose, (2) for recreation due to variations in design loads for different objectives and (3) for irrigation where economic consideration varied the estimates. Significant variation, but of lesser degree, were brought out (1) for hydroelectric power, where variations were due to site shifts alternated by site limitations, (2) for liquid waste disposal, where variations for environmental quality were due to additional treatment, storm sewer separation or dilution beyond agreed standards, (3) for flood control, where technical alternatives permitted variations and (4) for drainage, where these differences were mainly due to variation in the extent or type of areas drained.

6. For the remainder of the needs the numerical differences reported were small. The main reason for this is that existing methodology in these areas has not yet developed to a level making differentiation based on broad objectives clear and also because the methods of population and economic projections on which the demand estimates are based are still not clearly defined objective mixes, that is, not reflecting specific selected objectives. Nevertheless, even in these areas differentiation in the needs estimates is often possible even if only to indicate a demand that is likely to be greater or smaller than the one numerical value given.

7. The availability of alternatives was the subject of much discussion. Three types of alternatives appeared. One of these is the alternative siting of structural or non-structural measures. This appears to be an important alternative, but one that is generally beyond the scope of framework planning and in the perview of later more detailed planning

studies. Exceptions to this are power installations which can be moved between areas, recreation facilities that can serve needs generated in other areas, and water supplies by diversion from other basins. Most important in the framework context are the technological alternatives. The most signigicant ones appeared in the following areas. In water supply, development of surface and ground water appear as alternatives and both together as alternatives, usually the more advantageous ones, to diversion and desalinization. In the field of recreation, the alternatives are mainly the development of existing water area by access or change in use policy versus the development of new areas and beach areas versus swimming pools. In fish and wildlife conservation, dam removal and fishladders appear as alternatives on streams with significant anadromous fish potential. For solid waste, the alternatives are sanitary land fills, export of solid waste to some outside land or sea disposal areas, further compaction devices, and legal means to control throw away containers and other wastes. In liquid waste disposal the alternatives are advanced waste treatment and in dilution through low flow augmentation. Here cost factors appear to favor advanced waste treatment except where low flow augmentation can be developed in conjunction with other uses for the low flow. The interesting point was made that advanced waste treatment, especially of industrial wastes is very sensitive to changes in the composition of these wastes while dilution can be used generally on all wastes. Flood control alternatives center on structural versus non-structural damage reduction measures.

8. The most significant alternative, however, lies in variations of need satisfaction. The question allowing the greatest degree of freedom to select alternatives is "Should the need be fulfilled and if so to what degree?" In the third part of this report some selection is made to identify those needs that contribute most significantly to the different objectives.

9. In the remainder of this section there are tablulated the needs and suggested devices that were presented for each objective and each basin. When available, preliminary cost figures are shown; but as only some are available no totals are given. For each basin three Summary Tables are presented. Table 1 summarizes the needs and devices suggested for the Environmental Quality objective. Table 2 summarizes suggested needs and devices for National Efficiency (Income) and each Table 3 summarizes suggested needs and devices for Regional Development objectives.

BASIN SUMMARY

Area 9 Discussion of Opportunities Toward Objectives

1. The population of Area 9 is expected to increase from 4.3 million in 1960 to 8.1 million in the year 2020. Although this is a large increment in numbers, the rate of growth is substantially lower than for the NAR as a whole. Primary population centers are the Boston, Worcester and Providence-Pawtucket SMSA's. Area 9 includes almost all of the long coastline of Area B, including Cape Cod. The pappern of development is not expected to change radically from current trends. Most development will continue to be close to the existing metropolitan areas.

2. On considering investment toward the environmental quality objective, demands that deserve special emphasis include water supply for municipal and industrial and water quality (both with emphasis on urban quality components), recreation, health and visual and cultural quality. For withdrawal uses, irrigation would be given preference along with that portion of M & I that goes for industrial and commercial irrigation, golf courses and maintenance of farm landscape. For instream use, priority is given to recreation, fish and wildlife, solid waste disposal and liquid waste discharge. Industrial development is not precluded, but careful controls are required to insure that emphasis on environmental quality is accomplished with the least loss of industrial production; limits must be placed on the latter in favor of a higher quality. Legal devices are essential for obtaining this objective, including a range of tools to insure comprehensive and water use planning. For this objective, the demands in the summary list that should be met entirely would include (9) recreation, (1) M & I, (17) visual and cultural and, depending in part on efficiency costs, (12) water quality.

3. When considering investment toward the national income objective substantial investments are likely for efficiency in water supply (for municipal and industrial and selfsupplied industrial, power cooling and efficiency-oriented recreation) as indicated by the growth of population and employment and probably at least a modest increase in per capita use. Legal needs will be important insofar as the opportunity for more efficient regional organization of water supplies exists. Other needs will require less attention. Only minimal requirements for solid and liquid waste disposal and visual and cultural quality would be met. Of the estimates contained in the Summary Table No. 2 for Area 9, it could be expected that only those for demands (1) M & I, (2) Industry, (6) Power Cooling and (9) Recreation, would be fully met.

4. In considering investment toward the regional objective, demands that appear most promising include extensive recreation, fish and wildlife and navigation developments and water quality programs favoring industry. Other demands should be met with appropriate cost sharing and pricing policies. Extensive water supply investments for stimulating industry do not appear to be justified. Legal devices most relevent to this objective include changes in cost sharing and pricing policies. Water supply standards and waste disposal standards, if not provided by subsidy or general levy outside of the region, should be relaxed. On the summary sheets above, the demands that appear to have first priority for fulfillment include (8) navigation, (9) recreation and (10) fish and wildlife, with consideration given to a very deep draft regional port near Boston as a regional development aid.

PART III

EVALUATIONS AND DISCUSSIONS

1. This part contains some first evaluations of the material presented at the Plan Formulation Work Group sessions. Three areas of interpretations were covered. These are: (1) water balances, (2) a discussion of the plan elements that at this time appear as most advantageous towards each objective organized by basins and (3) some general overviews that seem relevant at this time.

2. Fresh-water balances for the three objectives are presented for each area. These balances are designed to compare the total needs in an area with the developable resource within the area and to thus provide an indication of apparent surplus or deficiency. An allowance is made for existing development including imports from other areas, but possible or planned future imports are not considered in these analyses. The balances will be further discussed after an explanation of the summaries of needs and resources.

3. Tables 1 through 6 contain available data on fresh-water withdrawal and in-stream needs.* Gross withdrawal needs are summarized in the first column under each benchmark year in Tables 1, 3, and 5. These data should generally agree with information presented elsewhere except that some special allowances have been made where necessary to better define rates of withdrawal during low-flow seasons. For example, the needs of the mineral industry have been adjusted to reflect an eight-hour working day before incorporation with the self-supplied industrial data. Thus, the totals may be somewhat higher than presented elsewhere. Also, irrigation withdrawal rates are highly dependent upon assumptions made as to device (see footnote for each table). In the case of the irrigation withdrawal from run-of-river flow, the rate has been based on use of one-half the year's volume requirement during a 30-day period. In the case of withdrawal from ground water and irrigation storage, the year's requirement was converted into an equivalent uniform annual rate.

4. The second column under each benchmark year in the withdrawal tables lists adjusted withdrawals (in parentheses) which have been calculated from the estimated reuse factors given below each table. The reuse factors were assigned to each need on the basis of present and expected conditions of use, and serve to develop an adjusted total withdrawal equivalent to the minimum rate of flow needed in order to satisfy all withdrawal needs, including consumption, without any unnecessary duplication. In areas where one-through power cooling is indicated (national efficiency objective) in fluvial waters, reuse factors were generally based on utilization of most of the practical development streamflows.

* Tables 1 and 2 always refer to Environmental Quality, Tables 3 and 4 to National Efficiency, and Tables 5 and 6 to Regional Development.

5. In-stream needs on Tables 2, 4, and 6 refer to minimum flow requirements for purposes such as run-of-river hydroelectric power generation, maintaining depths adequate for commercial navigation, recreational boating and swimming, providing flowing water and surface area for fishing and fish passage, diluting or assimilating wastes, repelling salinity in estuaries, etc. As in the case of adjusted total withdrawal, these data relate to total area outflow. They represent the need at or near the basin outlet, or a reflection of the average area need at the basin outlet. Since the same water can be used for several purposes, the critical need is considered to be the largest of the individual needs.

6. The availability of the fresh-water resource is indicated for each area in Table 7. Except for data relating to Department of Agriculture upstream reservoirs and ground water, availability is described in terms of shortage index.

7. Shortage index is defined as the sum of the squares of the annual shortages over a 100-year period where each shortage is expressed as a ratio to an annual target yield. A variety of shortage patterns or combinations would describe the same shortage index. For example, if the only shortage in 100 years occurred in one year, and amounted to 10% of the annual requirement, the shortage index would be $(0.10)^2$ or 0.01. Two annual shortages of 7% in 100 years would also be approximately equivalent to a shortage index of 0.01, since 2 $((0.07)^2 = 0.01$. A shortage index of 0.10 would imply ten times as many annual shortages of a given magnitude as would the index of 0.01; or the same number of shortages but each of about three times the magnitude.

8. For Table 7, existing streamflow corresponding to the selected shortage indices of 0.01 and 0.10 was determined from monthly streamflow records. For each of several trial flows, shortages were determined on a monthly basis, summed annually and the index calculated and adjusted to a 100-year basis. Approximation of 7-days flows have been made to provide a better indication of flows available for withdrawal and in-stream purposes, particularly where there is little existing regulation. Generally, these 7-day flows were determined by inspection of flow records, and application of a factor varying from about 0.5 to 1.0 to the monthly flow for a designated shortage index. Where 7-day flow frequency data from other studies were available, the factor was selected so that the 7-day flow would have a recurrence interval of about 50 years in the case of a shortage index of 0.01, and a recurrence interval of about 10 years for a shortage index of 0.10. It appears that this relationship prevails, approximately, in all areas.

9. Practical surface development streamflow is defined as the streamflow which could be made available by the addition of all useful storage which would appear reasonably feasible in an area. In most areas, storage development corresponding to this flow was based on a study of site listings

and available data, and selection was made of only those sites which appeared to be the most promising. While the criteria of storage selection would lean toward emphasis of the national efficiency objective, it is believed that the assumed practical development figures would equal or exceed amounts that might be considered within an area under programs emphasizing any of the three plan objectives.

10. Two separate determinations of practical surface development streamflow have been made. One with prospective major reservoir projects (storage generally > 25,000 A.F.) and one with potential upstream reservoir projects (storage < 25,000 A.F.). Although the yield as determined by the Department of Agriculture for the upstream projects has been based on a 1% probability of shortage rather than shortage index, it appears that this yield could be considered as comparable to that with a shortage index of 0.01 for the purposes of these computations.

11. A preliminary working estimate of the fresh ground-water potential in each area has been furnished by the U. S. Geological Survey. The maximum development (withdrawal) has been estimated at three-fourths the total recharge in an area. The practical development is considered to be the withdrawal rate that can be developed at justifiable costs, as determined by the hydrologic characteristics of the aquifers. Municipal and industrial ground water is available in units of 500 gpm or more per well, and will ordinarily deplete streamflow by nearly the amount shown. (In most instances, large industries and cities are located near or on major streams). The rural ground water which could be practically developed is a fraction of maximum withdrawal and is the total water that can be developed by lower yield wells at reasonable cost. It would not be expected that the total rural withdrawal could be utilized without subtractive effect on streamflow.

12. The extra ground water shortage equivalent refers to a reserve of water that may be pumped from sandstone, limestone, and sand formations once every 5 years for about four months without producing significant effect on the low flow of major streams at that time. Storage in shales and crystalline rocks has not been considered since well yields here are small and water produced is more expensive.

13. The assumed total developable resource listed at the bottom of Table 7 has been computed by adding to the practical surface development streamflow with major reservoirs, (1) the incremental yield of the upstream reservoirs, or a specified portion thereof, and (2) the practically developable rural ground water. Then, from the sum is subtracted an allowance for overlap in yield such as might occur due to competition between major and upstream reservoir development or the subtractive effects of ground-water development on streamflow. The allowance varies from about 5 to 15% with the highest figure used in areas where total prospective development would be the highest (in comparison with average annual runoff).

14. The water balances on Table 8 compare adjusted withdrawal and critical in-stream need with assumed total developable resource for each objective. In the case of the withdrawal balance, the adjusted withdrawal is compared with the developable resource for a shortage index of 0.01, the most severe risk level considered appropriate for the purposes of this study. For the in-stream balance, somewhat less severe criteria are applicable and the developable resource for a shortage index of 0.10 is compared with the sum of the critical in-stream need and the increase in consumption over the present. The addition of incremental consumption to the in-stream need allows for a reduction in available resource with time due to increased usage and loss. For simplicity, no allowance has been made for phasing of development, and the total developable resource has been used for each benchmark year.

15. In interpreting the balances, it should be kept in mind that in some areas satisfaction of either an in-stream or withdrawal deficiency could also satisfy the other, and therefore the most critical balance would govern in describing an area's overall situation. In other areas, satisfaction of either category of need might not affect the other, and the balance results would be additive in nature. Also, since the balances reflect data for large areas, local areas of surplus or deficiency could well be masked by the results.

16. Area deficiency in withdrawal indicates that the resources of an area could probably not be developed for satisfaction of the area's needs, and importation of water from an area of surplus, would be likely. Significant deficiency in an area with regard to in-stream need in these analyses would generally appear to indicate that low flow augmentation would not be a practical alternative to advanced waste treatment, at least on an area-wide basis.

17. The balances serve to indicate the areas in which significant deficiencies are likely together with the approximate magnitude of flow involved as well as those areas in which surplus could be developed. However, there is no implication that conventional development within an area is less expensive or preferrable to the use of importation or other devices.

18. Preceding the Basin Summary Tables, the long sheets in back of the report , are the water balances, Tables 1-8, for each of the areas of the NAR.

19. The material contained in Part II was reviewed and discussed by Professor Zube of the University of Massachusetts, Colonel Froelich, a regional planner on a short tour of active duty, the Planning Associates of the Board of Engineers for Rivers and Harbors, and members of the NAR and NAD staffs. The purpose of these discussions was to elicit opinions as to the importance of the various needs to the objectives and to set down these opinions as a base for further discussion. The remainder of this section consists of the summaries of these discussions added as inserts into this report after each basin's summary tables.

20. Out of the entire first phase of plan formulation some general conclusions can be drawn. Our work has shown that the choice of objectives can significantly affect the type of program to support these objectives. The lack of experience in multiple objective planning, however, has been painfully obvious. This lack points towards continued work on both the concepts and the realities of the problem. These realities express themselves in gaps of our knowledge of how the use and development of water and land resources relate to the social objectives of an improved environmental quality, of national efficiency (income) maximization or of emphasis on regional development. Our general views on programs emphasizing each of the three objectives, based on our experience to date, is contained in the following sections of this report.

21. The environmental quality objective empahsizes water quality; water supply for urban areas and for agriculture; the preservation or protection of important biological, visual and cultural resources; control of solid and liquid wastes; recreation; flood and erosion control; health; and related legal needs. The degree of importance of the individual needs varies from basin to basin as the basin varies from predominantly urban to rural. The objective requires both the enactment and the enforcement of high environmental quality standards and the concomitant acceptance of planned and limited physical growth and development.

22. Water supply for urban needs must meet esthetic as well as normal municipal utilitarian needs. Water should be available in quantities sufficient for city sanitation; for irrigation of parks, golf courses and lawns; for fountains; air conditioning; etc. Water should be provided to meet the irrigation needs for agriculture to help sustain agriculture as an important aspect of both the cultural and the visual landscape.

23. Historic sites, unique or important biological resources and outstanding scenic resources should be preserved by appropriate state or federal action. Other high quality landscapes should be protected by the enforcement of land use controls that guide development in harmony with the natural and cultural resource base. Water oriented recreational opportunities should be provided to satisfy the needs of the relatively immobile center-city inhabitant as well as the more mobile fringe city dweller. This implies access to urban water fronts and vastly improved

water quality in urban rivers as well as ample water for street spray, fountains and swimming pools. A range of opportunities should be provided that encompasses center-city needs, ocean-shore beaches, recreational lakes and reservoirs as well as wild and scenic rivers. Areas with high potential for satisfying recreation demands should be made accessible to the inhabitants of the large population centers.

24. In summary, the environmental quality objective focuses on preserving the existing highest value or unique natural and cultural resources, protecting other high value resources through controlled development, vastly improving sub-standard resources to maximum practical quality levels and providing the widest possible latitude and the greatest number of opportunities for people to use water for esthetic as well as utilitarian needs.

25. For the national efficiency (national income) objective, the key is the fulfillment of those demands that are supportable if organized on a free market basis. While original estimates may provide a general order of magnitude, these demand estimates should be carefully examined in terms of costs in order to determine the extent to which demand projections should be met. Only those amounts of water system outputs should be supplied that will result in the largest net contributions to national output. In the planning methodology used here, reasonable modifications in this rule are mandated in order not to produce plans or programs that are so extreme in emphasizing one objective that they do not provoke useful discussion.

26. In general, population and productivity increases in most NAR basins will require substantially increased amounts of water system outputs for increasing the national income. However, these amounts supplied should be considered carefully in terms of supportable shortage indices, certainty of delivery, and other concepts. Substantial additional supplies of water for M & I, industrial use, recreation, and power can be contemplated in general under this objective. Regionalization of water systems and careful pricing policies become important under this objective, as do the careful investigation of optimal combinations for least cost of ground water and surface supplies. Water quality programs become less important except insofar as they contribute to increasing the national income. This might be the case where recreation demands are heavy, for example, but it should be recognized that in many cases high water quality standards may not be justified on the basis of this objective. Expensive solid waste disposal systems may also be unjustified. Some measures for erosion control, drainage, and irrigation may be justified, as will certain visual and cultural quality devices required to sustain productivity in a region on the theory that productivity is increased most where at least minimal amenities are provided. Navigation and flood control investments can be contemplated, although the latter may include stricter management measures than are usual now.

27. For the regional development objective, the key is the fulfillment of those demands that, when fulfilled and combined with repayment and tax policies, promise the greatest net income, employment or production gains to the region in question. The criterion for inclusion in a program emphasizes the regional contribution of devices and needs and does not depend exclusively on the usual benefit-cost (national income version) criterion. Thus, programs will include investments that might not be justified under the national income or the environmental quality criteria. The regional program thus has two sides. The first is the analysis of those investments through which the greatest economic contribution can be made to the region, leaving aside repayment and tax policies. In a rural, underdeveloped area, for example, such a need might be recreation. In other more developed areas, programs might focus on industrial water supply or water quality programs required by industry (not by law) financed not by industry but by general funds from outside the region. The regional program might also depend on relation of budgetary constraints for water resource investment within a given region but not in other regions; and it may involve investments for environmental quality where these are required to increase economic activity in a region (e.g. in the Northern areas of the NAR). In other areas, environmental quality constraints might be greatly relaxed if regional economic advances are the criterion on investment. This would include, for example, water quality programs where improved quality is not required for industry.

TABLE 1 - FRESH WATER WITHDRAWAL NEEDS (C.F.S.)

	1980		2000		2020	
Public Municipal & Industrial	1,132	(1,025)	1,520	(1,380)	2,100	(1,910)
Self-Supplied Industrial	422	(210)	629	(314)	906	(450)
Rural Water Supply	78	(22)	148	(42)	180	(51)
Irrigation 7/	293	(293)	335	(335)	440	(440)
Power Cooling 2/	-	-	-	-	-	-
Total	1,925		2,632		3,626	
Adjusted Total 1/		(1,550)		(2,071)		(2,851)

Estimated Reuse Factors

M. & I.	1.1	Reuse limited by location and device
Ind.	2.0	Ave., little reuse in eastern portion, signif. in West.
Rural	3.5	Mostly ground water, allow. for consumption
Irrigation	1.0	Mostly consumptive
Power Cooling		

TABLE 2 - FRESH WATER IN-STREAM NEEDS (C.F.S.)

	1980	2000	2020
Hydroelectric	3/	3/	3/
Navigation			
Recreation	6/	6/	6/
Fish & Wildlife	1,000	1,000	1,000
Waste Discharge 4/	1,290 5/	1,290 5/	1,940 5/
Critical Need	1,290	1,290	1,940

1/ See estimated reuse factors
2/ Total withdrawal assumed from coastal waters.
3/ No projected add'l development thru 2020
4/ Min. pres. flow, S.I. = 10, 7-day = 1290 cfs, 50% increase in 2020 in lieu of AWTR.
5/ Hydro. operation should permit maintenance of flow thru weekends.
6/ Optimum activity in selected reaches would require maintenance of May mean monthly flows.
7/ Assumed ½ of withdrawal from run-of-river flow and ½ from groundwater and storage.

TABLE 3 - FRESH WATER WITHDRAWAL NEEDS (C.F.S.)

	1980		2000		2020	
Public Municipal & Industrial	1132	(1030)	1520	(1380)	2100	(1910)
Self-Supplied Industrial	422	(211)	629	(314)	906	(453)
Rural Water Supply	78	(22)	148	(42)	180	(51)
Irrigation 1/	275	(275)	309	(309)	420	(420)
Power Cooling 2/	—	—	—	—	—	—
Total	1895		2606		3606	
Adjusted Total 4/		(1536)		(2045)		(2834)

Estimated Reuse Factors

M. & I.	1.1
Ind.	2.0
Rural	3.5
Irrigation	1.0
Power Cooling	—

TABLE 4 - FRESH WATER IN-STREAM NEEDS (C.F.S.)

	1980		2000		2020	
Hydroelectric		5/		5/		5/
Navigation						
Recreation		6/		6/		6/
Fish & Wildlife	1,000		1,000		1,000	
Waste Discharge 4/	1,290	5/	1,290	5/	1,940	5/
Critical Need	1,290		1,290		1,940	

1/ See estimated reuse factors
2/ Total withdrawal assumed from coastal waters
3/ No projected add'l development thru 2020
4/ Min. pres. flow, S.I. 10, 7day = 1290 cfs. 50% increase in 2020 in lieu of AWTR.
5/ Hydro. operation should permit maintenance of flow thru weekends.
6/ Optimum activity in selected reaches would require maintenance of Mary mean monthly flows.
7/ Assumed 1/2 of withdrawal from run-of-river flow and 1/2 from groundwater and storage.

TABLE 5 - FRESH WATER WITHDRAWAL NEEDS (C.F.S.)

	1980		2000		2020	
Public Municipal & Industrial	1132	(1030)	1520	(1380)	2180	(1910)
Self-Supplied Industrial	422	(211)	629	(314)	906	(453)
Rural Water Supply	78	(22)	148	(42)	180	(51)
Irrigation 3/	286	(286)	332	(332)	431	(431)
Power Cooling 2/	–	–	–	–	–	–
Total	1918		2629		3617	
Adjusted Total 1/		(1549)		(2068)		(2845)

Estimated Reuse Factors

M. & I.	1.1
Ind.	2.0
Rural	3.5
Irrigation	1.0
Power Cooling	–

TABLE 6 - FRESH WATER IN-STREAM NEEDS (C.F.S.)

	1980	2000	2020
Hydroelectric	3/	3/	3/
Navigation			
Recreation	6/	6/	6/
Fish & Wildlife	1,000	1,000	1,000
Waste Discharge 4/	1,290 5/	1,290 5/	1,940 5/
Critical Need	1,290	1,290	1,940

1/ See estimated reuse factors.
2/ Total withdrawal assumed from coastal waters.
3/ No projected add'l development thru 2020
4/ Min. pres. flow S.I. 10, 7 day = 1290 cfs. 50% increase in 2020 in lieu of AWTR.
5/ Hydro. operation should permit maintenance of flow thru weekends.
6/ Optimum activity in selected reaches would require maintenance of May mean monthly flows.
7/ Assumed 1/2 of withdrawal from run-of-river and 1/2 from ground water and storage.

AREA 9

TABLE 7 - WATER RESOURCES AVAILABILITY (C.F.S.)

Average Annual Runoff	8,200
Existing Streamflow 1/	
shortage index 0.01 (monthly flow)	1,780
shortage index 0.01 (approx. 7-day flow)	1,065
shortage index 0.10 (monthly flow)	2,150
shortage index 0.10 (approx. 7-day flow)	1,290
Practical Surface Development Streamflow	
with major reservoirs (S.I.=0.01) 2/	1,735
with major reservoirs (S.I.=0.10) 2/	2,030
with upstream reservoirs (1% chance shortage) 3/	1,710 4/
Ground Water Potential	
maximum development	1880
practical development (municipal, industrial)	542 6/
practical development (rural)	375
extra storage equivalent	Small
Assumed Developable Resource	
shortage index 0.01	2,200 5/
shortage index 0.10	2,580

1/ Excludes present yield of MDC reservoir system.
2/ Includes present MDC reservoir system plus approx. 100,000 A.F. of additional storage.
3/ Estimate 219,700 A.F. of additional storage at 87 sites.
4/ Consistent gross yield from controlled area (441 cfs) plus allowance for minimum flow from the remaining area plus the present MDC system yield.
5/ Based on surface development streamflow with major reservoirs plus incremental yield of 1/2 the upstream reservoirs plus additional ground water (rural) less an allowance for estimated overlap in yield.
6/ Cape Cod excluded.

TABLE 8 - WATER RESOURCE BALANCES (C.F.S.)

Developable Resource
Shortage Index 0.01 — 2,200
Shortage Index 0.10 — 1,930 2/

ENVIRONMENTAL QUALITY

	1980	2000	2020
Adjusted Withdrawal	1,550	2,071	2,851
In-Stream Need	1,290	1,290	1,940
Consumption 1/	260	370	580
Withdrawal Balance 3/			
Excess (+) or Deficiency (-)	+ 650	+ 129	- 651
In-Stream Balance 4/			
Excess (+) or Deficiency (-)	+ 380	+ 270	- 590

NATIONAL EFFICIENCY (INCOME)

	1980	2000	2020
Adjusted Withdrawal	1,536	2,045	2,834
In-Stream Need	1,290	1,290	1,940
Consumption 1/	240	350	570
Withdrawal Balance 3/			
Excess (+) or Deficiency (-)	+ 664	+ 155	- 634
In-Stream Balance 4/			
Excess (+) or Deficiency (-)	+ 400	+ 290	- 580

REGIONAL DEVELOPMENT

	1980	2000	2020
Adjusted Withdrawal	1,549	2,068	2,845
In-Stream Need	1,290	1,290	1,940
Consumption 1/	250	370	570
Withdrawal Balance 3/			
Excess (+) or Deficiency (-)	+ 651	+ 132	- 645
In-Stream Balance 4/			
Excess (+) or Deficiency (-)	+ 390	+ 270	- 580

1/Incremental (estimate of increase over present)

2/ Assume that ½ of add'l development would be available for in-stream use. Thus from Table-7, ½(1290 + 2580) = 1930 cfs.

3/ Developable resource (S.I. .01) minus adjusted withdrawal.

4/ Developable resource (S.I. .10) minus sum of in-stream need and consumption.

NAR Area 9 - Summary Table 1

	1980	2000	2020
1. Municipal and Industrial Water Supply			
	Demand 730 mgd, 160 mgd increment over present. Suggested devices: 160,000 AF storage; 40 mgd wells; 70 mgd diversion; river intakes; 80 mgd treatment plants; tunnels and pipelines. First cost: Surface water $69.0 million Ground water 4.0 million Total $73.0 million	Demand 990 mgd, 260 mgd increment over year 1980. Suggested devices: 35,000 AF storage, 70 mgd wells; 120 mgd diversion; river intakes; 75 mgd treatment plants; tunnels and pipelines. First cost: Surface water $75.0 million Ground water 7.0 million Total $82.0 million	Demand 1370 mgd, 380 mgd increment over year 2000. Suggested devices: 23,000 AF storage: 120 mgd wells; river intakes: 180 mgd treatment plants; tunnels and pipelines: and 100 mgd diversion from other areas. First cost: Surface water $66.0 million Ground water 12.0 million Total $78.0 million
2. & 5. Self-Supplied Industrial Process and Cooling Water			
	Demand 230 mgd, 90 mgd increment over present. Suggested devices: River intakes and 15 mgd wells. First cost: $1.5 million for wells.	Demand 340 mgd, 110 mgd increment over year 1980. Suggested devices: River intakes and 20 mgd wells. First cost: $2.0 million for wells.	Demand 500 mgd, 160 mgd increment over year 2000. Suggested devices: River intakes and 35 mgd wells. First cost: $3.5 million for wells.
3. Rural Domestic and Livestock Water Supply			
	Demand 50 mgd, 26 mgd over present. Suggested devices: 26 mgd wells. First cost: $2.6 million	Demand 95 mgd, 45 mgd over year 1980. Suggested devices: 45 mgd wells. First cost: $4.5 million	Demand 117 mgd, 22 mgd over year 2000. Suggested devices: 22 mgd wells. First cost: $2.2 million
4. Irrigation Water Supply			
	Yearly demand 60,000 AF, 40,000 AF increment over present. Suggested devices: 16,000 AF storage and 24,000 AF wells and streams. First cost $15.3 million Annual cost $ 3.2 million	Yearly demand 70,000 AF, 17,000 AF increment over year 1980. Suggested devices: 8,500 AF storage and 8,500 AF wells and streams. First cost $21.2 million Annual cost $ 4.1 million	Yearly demand 91,000 AF, 21,000 AF increment over year 2000. Suggested devices: 13,000 AF storage and 8,000 AF wells and streams. First cost $12.1 million Annual cost $ 1.3 million

NAR Area 9 - Summary Table 1 (Cont'd)

1980	2000	2020
6. Power Cooling Water		
Demand 210 cfs consumptive water from the coastal waters for 13,000 mw total power installation with cooling towers.	Demand 530 cfs consumptive water from coastal waters for 35,000 mw total power installation with cooling towers.	Demand 1,700 cfs consumptive water from the coastal waters for 113,000 mw total power installation with cooling towers.
7. Hydroelectric Power		
Hydroelectric power generation not anticipated.	Hydroelectric power generation not anticipated.	Hydroelectric power generation not anticipated.
8. Navigation		
Annual tonnage 61.0 million, 18.0 million over present. Suggested devices: Deepening and widening of certain channels within the Port of Boston. First cost: $47.0 million	Annual tonnage 96.0 million, 35.0 million over year 1980. Suggested devices: Further deepening and widening of channels within the Port of Boston; deepening and widening of Salem Harbor channel; and deepening of Providence River and Harbor channel, New Bedford Harbor channel, and Cape Cod Canal. First cost: $112.0 million	Annual tonnage 150.0 million, 54.0 million over year 2000. Suggested devices: Further deepening of Port of Boston channels, Providence River and Harbor channel, and Cape Cod Canal. First cost: $172.0 million
9. Recreation		
Total water oriented recreation days 92.0 million. Demand: Water surface acres by minimum unit size: >500:200,000 >200:60,000 >10:12,000 Stream miles 629; Beach acres 1,600 or swimming pool sq. ft. 27.0 million; Land acres 118,000. Possible devices: Expansion of existing sites; utilization of untapped resources; new reservoirs; changes in design loads of existing facilities; conversion of existing projects to include recreation; improvement of transportation system; navigation improvement; and beach erosion control. Definition of need for in-depth studies to determine adequacy of existing water quality classification system.	Incremental water-oriented recreation days 54.0 million. Incremental demand: Water surface acres by minimum size: >500:103,000 >200:30,000 >10:5,900; Stream miles 190; Beach acres 480 or swimming pool sq. ft. 8.3 million; Land acres 41,000. Possible devices: Same as for 1980.	Incremental water-oriented recreation days 166.0 million. Incremental demand: Water surface acres by minimum size: >500:130,000 >200:43,000 >10:6,300; Stream miles 100; Beach acres 32 or swimming pool sq. ft. 5.6 million; Land acres 41,000. Possible devices: Same as for 1980.

NAR Area 9 - Summary Table 1 (Cont'd)

1980	2000	2020
10. Fish and Wildlife		
Fishing: 9.7 million man days, 1.8 million over present. Wildlife: 1.7 million man days, 0.2 million over present. Suggested devices: Fishing: 430 acres of freshwater access: 140 acres of saltwater access; and maintaining existing habitat and water quality. Wildlife: Maintaining habitat consistent with land use projections and providing access: hunting regulations that allow maximum sustained yield of big game: hunting regulations for small game; and maintaining waterfowl habitat at 1965 level. First cost: Freshwater access $4.1 million Saltwater access 1.4 million Total $5.5 million Annual cost: Freshwater access $0.7 million Saltwater access 0.2 million Total $0.9 million	Fishing: 12.6 million man days, 3.0 million over year 1980. Wildlife: 2.0 million man days, 0.3 million over year 1980. Suggested devices: Fishing: Opening single purpose water supply reservoirs and providing access to private lakes; 170 acres of freshwater access: and 240 acres of saltwater access. Wildlife: Same as for 1980 but maintaining small game habitat at year 2000 level. First cost: Freshwater access $1.9 million Saltwater access 2.8 million Total $4.7 million Annual cost: Freshwater access $0.3 million Saltwater access 0.4 million Total $0.7 million	Fishing: 16.0 million man days, 3.4 million over year 2000. Wildlife: 2.4 million man days, 0.4 million over year 2000. Suggested devices: Fishing: 20,000 surface acres of impoundments; 200 acres of freshwater access: and 280 acres of saltwater access. Wildlife: Same as for 1980 but maintaining small game habitat at year 2000 level. First cost: Freshwater access $1.6 million Saltwater access 2.4 million Total $4.0 million Annual cost: Freshwater access $0.3 million Saltwater access 0.4 million Total $0.7 million
11. Solid Waste Disposal		
Annual quantity of solid waste 6,700 AF, 3,700 AF over present. 6,000 acres required for sanitary fill to 1980.	Annual quantity of solid waste 11,300 AF, 4,600 AF over year 1980. 26,000 acres required for sanitary fill between 1980 and 2000.	Annual quantity of solid waste 17,000 AF, 5,700 AF over year 2000. 40,000 acres required for sanitary fill between 2000 and 2020.

NAR Area 9 - Summary Table 1 (Cont'd)

1980	2000	2020
12. Liquid Waste Disposal		
Total untreated waste load 11.1 million PE. Suggested devices: Secondary treatment (85% Removal), reducing waste discharge to 1.7 million PE. First cost: $775 million Control of combined and stormwater discharge and control of nutrients (nitrates and phosphates), costs of which are presently not available.	Total untreated waste load 16.3 million PE. Suggested devices: Secondary treatment (90% Removal), reducing waste discharge to 1.6 million PE; advance waste treatment at specific locations (95% Removal), further reducing waste discharge to 0.8 million, or low flow augmentation in lieu of advance waste treatment. First cost: Secondary treatment $1,142 million Advance waste treatment 98 million Total $1,240 million Detailed studies before 2000. Control of combined and stormwater discharge and control of nutrients (nitrates and phosphates), costs of which are presently not available.	Total untreated waste load 25.0 million PE. Suggested devices: Secondary treatment (90% Removal), reducing waste discharge to 2.5 million PE; advance waste treatment (95% Removal), further reducing waste discharge to 1.5 million PE, or low flow augmentation in lieu of advance waste treatment. First cost: Secondary treatment $1,745 million Advance waste treatment 150 million Total $1,895 million Control of combined and stormwater discharge and control of nutrients (nitrates and phosphates), the costs of which are presently not available.
13. Flood Control		
Mainstem: Total average annual flood damage $11.1 million, $4.0 million over present. Suggested devices: Flood plain management, reducing average annual damage by $4.4 million. Upstream watersheds: Total average annual flood damage $6.5 million, $2.5 million over present. Suggested devices: 63 small dams impounding 71,000 AF of flood flow, reducing total average annual damage by $1.0 million. First cost: $14.0 million Annual cost: $ 0.8 million	Main stem: Total average annual flood damage $21.2 million, $10.1 million over year 1980. Suggested devices: Flood plain management, reducing total average annual damage by $13.5 million. Upstream watersheds: Total average annual damage $12.2 million, $5.7 million over year 1980. Suggested devices: No additional improvements, but total average annual damage reduced by $2.0 million by 1980 improvements.	Main stem: Total average annual damage $42.6 million, $21.4 million over year 2000. Suggested devices: Flood plain management, reducing total average annual damage by $33.3 million. Upstream watersheds: Total average annual damage $24.0 million, $11.8 million over year 2000. Suggested devices: No additional improvements, but total average annual damage reduced by $5.0 million by 1980 improvements.
14. Drainage		
Suggested devices: Draining 3,000 acres of cropland by watershed management (tile, surface drains, open ditch or pumps) and channel improvement. First cost: $0.2 million	Suggested devices: Draining 6,000 acres of cropland and 2,000 acres of forestland by watershed management and channel improvement. First cost: $0.4 million	Suggested devices: Draining 1,000 acres of cropland and 7,000 acres of forestland by watershed management and channel improvement. First cost: $0.3 million

NAR Area 9 - Summary Table 1 (Cont'd)

1980	2000	2020
15. Erosion Control		
Suggested devices: Erosion control on 96,000 acres by watershed management (diversion, waterways, strip cropping, cover cropping, etc.), reducing sediment load by 21,000 cubic yards annually. First cost: $5.6 million Annual cost: $0.4 million	Suggested devices: Erosion control on 242,000 acres by watershed management, reducing sediment load by 76,000 cubic yards annually. First cost: $17.3 million Annual cost: $ 1.1 million	Suggested devices: Erosion control on 355,000 acres by watershed management, reducing sediment load by 162,000 cubic yards annually. First cost: $26.5 million Annual cost: $ 1.6 million
16. Health Aspects		
Suggested devices: Insect control: facilities for recreation; and a water hygiene laboratory.	Suggested devices: Insect control and facilities for recreation.	Suggested devices: Insect control and facilities for recreation.
17. Visual and Cultural Environment		
Suggested improvements: Protection of 1,000 sq. mi. of unique landscape and coastline; protection of cultural and historic sites in urban areas including environment; improvement of water quality; and use of river design potential.	Suggested improvements: Provision of ammenities within the area; creation of 200 sq. mi. of town/farm landscape: and improvement of quality and absorptive capacity of 2,100 sq. mi. of forest landscape.	
18. Legal Measures		
Suggested measures: Establishment of interstate fishing compact within NAR area; establishment of State control of wildlife resources and anadromous and shellfish fisheries; and revision of planning and zoning laws.		

NAR Area 9 - Summary Table 2

	1980	2000	2020
1. Municipal and Industrial Water Supply			
	Demand 730 mgd, 160 mgd increment over present. Suggested devices: 160,000 AF storage; 40 mgd wells; 70 mgd diversion; river intakes; 80 mgd treatment plants; tunnels and pipelines. First cost: Surface water $69.0 million Ground water 4.0 million Total $73.0 million	Demand 990 mgd, 260 mgd increment over year 1980. Suggested devices: 35,000 AF storage, 70 mgd wells; 120 mgd diversion; river intakes; 75 mgd treatment plants; tunnels and pipelines. First cost: Surface water $75.0 million Ground Water 7.0 million Total $82.0 million	Demand 1370 mgd, 380 mgd increment over year 2000. Suggested devices: 23,000 AF storage; 120 mgd wells; river intakes; 180 mgd treatment plants; tunnels and pipelines; and 100 mgd diversion from other areas. First cost: Surface water $66.0 million Ground water 12.0 million Total $78.0 million
2. & 5. Self-Supplied Industrial Process and Cooling Water			
	Demand 230 mgd, 90 mgd increment over present. Suggested devices: River intakes and 15 mgd wells. First cost: $1.5 million for wells.	Demand 340 mgd, 110 mgd increment over year 1980. Suggested devices: River intakes and 20 mgd wells. First cost: $2.0 million for wells.	Demand 500 mgd, 160 mgd increment over year 2000. Suggested devices: River intakes and 35 mgd wells. First cost: $3.5 million for wells.
3. Rural Domestic and Livestock Water Supply			
	Demand 50 mgd, 26 mgd over present. Suggested devices: 26 mgd wells. First cost: $2.6 million	Demand 95 mgd, 45 mgd over year 1980. Suggested devices: 45 mgd wells. First cost: $4.5 million	Demand 117 mgd, 22 mgd over year 2000. Suggested devices: 22 mgd wells. First cost: $2.2 million
4. Irrigation Water Supply			
	Yearly demand 56,000 AF, 36,000 AF increment over present Suggested devices: 14,500 AF storage and 21,500 AF wells and streams. First cost: $8.0 million Annual cost: $1.0 million	Yearly demand 64,000 AF, 17,000 increment over year 1980. Suggested devices: 8,500 AF storage and 8,500 AF wells and streams. First cost: $12.6 million Annual cost: $ 1.3 million	Yearly demand 87,000 AF, 23,000 increment over year 2000. Suggested devices: 14,000 AF storage and 9,000 AF wells and streams. First cost: $16.3 million Annual cost: $ 1.7 million

NAR Area 9 - Summary Table 2 (Cont'd)

1980	2000	2020
6. Power Cooling Water		
Demand 20,000 cfs once-through cooling water and 140 cfs consumptive water from the coastal waters, at no cost, for 13,000 mw total power installation.	Demand 37,000 cfs once-through cooling water and 300 cfs consumptive water from the coastal waters, at no cost, for 30,000 mw total power installation	Demand 95,000 cfs once-through cooling water and 1,000 cfs consumptive water from the coastal waters, at no cost, for 98,000 mw total power installation.
7. Hydroelectric Power		
Hydroelectric power generation not anticipated.	Hydroelectric power generation not anticipated.	Hydroelectric power generation not anticipated.
8. Navigation		
Annual tonnage 61.0 million, 18.0 million over present. Suggested devices: Deepening and widening of certain channels within the Port of Boston. First cost: $47.0 million	Annual tonnage 96.0 million, 35.0 million over year 1980. Suggested devices: Further deepening and widening of channels within the Port of Boston; deepening and widening of Salem Harbor channel; and deepening of Providence River and Harbor channel, New Bedford Harbor channel , and Cape Cod Canal. First cost: $112.0 million	Annual tonnage 150.0 million, 54.0 million over year 2000. Suggested devices: Further deepening of Port of Boston channels, Providence River and Harbor channel , and Cape Cod Canal. First cost: $172.0 million
9. Recreation		
Total water-oriented recreation days 80.0 million. Demand: Water surface acres by minimum unit size: > 500:61,000 > 200:14,000 >10:2,000 Stream miles 207; Beach acres 600 or swimming pool sq. ft. 11.0 million; Land acres 22,000 Possible devices: Expansion of existing sites; utilization of untapped resources; new reservoirs; changes in design loads of existing facilities; conversion of existing projects to include recreation; improvement of transportation system. Definition of need for in-depth studies to determine adequacy of existing water quality classification system.	Incremental water-oriented recreation days 50.0 million. Incremental demand: Water surface acres by minimum size: >500:32,000 > 200:7,000 >10:1,000; Stream miles 64; Beach acres 180 or swimming pool sq. ft. 3.5 million; Land acres 7,500. Possible devices: Expansion of existing sites; utilization of untapped resources; new reservoirs; changes in design loads of existing facilities; conversion of existing projects to include recreation; improvement of transportation system.	Incremental water-oriented recreation days 72.0 million. Incremental demand: Water surface acres by minimum size: >500:15,000 > 200:4,700 >10:1,000; Stream miles 33; Beach acres 97 or swimming pool sq. ft. 1.9 million; Land acres 4,300. Possible devices: Expansion of existing sites; utilization of untapped resources; new reservoirs; changes in design loads of existing facilities; conversion of existing projects to include recreation; improvement of transportation system.

1980	2000	2020
10. Fish and Wildlife		
Fishing: 9.7 million man days, 1.8 million over present. Wildlife: 1.7 million man days, 0.2 million over present. Suggested devices: Fishing: 20,000 surface acres of impoundments, including those obtained by opening of single purpose water supply reservoirs and providing access to private lakes; 430 acres of freshwater access; 140 acres of saltwater access; and maintaining existing habitat and water quality. Wildlife: Maintaining habitat consistent with land use projections and providing access; hunting regulations that allow maximum sustained yield of big game; hunting regulations for small game; and maintaining waterfowl habitat at 1965 level. First cost: Freshwater access $4.1 million Saltwater access 1.4 million Total $5.6 million Annual cost: Freshwater access $0.7 million Saltwater access 0.2 million Total $0.9 million	Fishing: 12.6 million man days, 3.0 million over year 1980. Wildlife: 2.0 million man days, 0.3 million over year 1980. Suggested devices: Same as for 1980, except for access (170 acres of freshwater access and 240 acres of saltwater access) and maintaining small game habitat at year 2000 level. First cost: Freshwater access $1.9 million Saltwater access 2.8 million Total $4.7 million Annual cost: Freshwater access $0.3 million Saltwater access 0.4 million Total $0.7 million	Fishing: 16.0 million man days, 3.4 million over year 2000. Wildlife: 2.4 million man days, 0.4 million over year 2000. Suggested devices: Same as for 1980, except for access (200 acres of freshwater access and 280 acres of saltwater access) and maintaining small game habitat at year 2000 level. First cost: Freshwater access $1.6 million Saltwater access 2.4 million Total $4.0 million Annual cost: Freshwater access $0.3 million Saltwater access 0.4 million Total $0.7 million
11. Solid Waste Disposal		
Annual quantity of solid waste 6,700 AF, 3,700 AF over present. 6,000 acres required for sanitary fill to 1980.	Annual quantity of solid waste 11,300 AF, 4,600 AF over year 1980. 26,000 acres required for sanitary fill between 1980 and 2000.	Annual quantity of solid waste 17,000 AF, 5,700 AF over year 2000. 40,000 acres required for sanitary fill between 2000 and 2020.

NAR Area 9 - Summary Table 2 (Cont'd)

1980	2000	2020
12. Liquid Waste Disposal		
Total untreated waste load 11.1 million PE. Suggested devices: Secondary treatment (85% Removal), reducing waste discharge to 1.7 million PE. First cost: $775 million	Total untreated waste load 16.3 million PE. Suggested devices: Secondary treatment (90% Removal), reducing waste discharge to 1.6 million PE; advance waste treatment at specific locations (95% Removal), further reducing waste discharge to 0.8 million, or low flow augmentation in lieu of advance waste treatment. First cost: Secondary treatment $1,142 million Advance waste treatment 98 million Total $1,240 million Detailed studies before 2000.	Total untreated waste load 25.0 million PE. Suggested devices: Secondary treatment (90% Removal), reducing waste discharge to 2.5 million PE; advance waste treatment (95% Removal), further reducing waste discharge to 1.5 million PE, or low flow augmentation in lieu of advance waste treatment. First cost: Secondary treatment $1,745 million Advance waste treatment 150 million Total $1,895 million
13. Flood Control		
Main stem: Total average annual flood damage $11.1 million, $4.0 million over present. Suggested devices: Flood plain management, reducing average annual damage by $4.4 million. Upstream watersheds: Total average annual flood damage $6.5 million, $2.5 million over present. Suggested devices: 63 small dams impounding 71,000 AF of flood flow, reducing total average annual damage by $1.0 million. First cost: $14.0 million Annual cost: $ 0.8 million	Main stem: Total average annual flood damage $21.2 million, $10.1 million over year 1980. Suggested devices: Flood plain management, reducing total average annual damage by $13.5 million. Upstream watersheds: Total average annual damage $12.2 million, $5.7 over year 1980. Suggested devices: No additional improvements, but total average annual damage reduced by $2.0 million by 1980 improvements.	Main stem: Total average annual damage $42.6 million, $21.4 million over year 2000. Suggested devices: Flood plain management, reducing total average annual damage by $33.3 million. Upstream watersheds: Total average annual damage $24.0 million, $11.8 million over year 2000. Suggested devices: No additional improvements, but total average annual damage reduced by $5.0 million by 1980 improvements.
14. Drainage		
Suggested devices: Draining 2000 acres of cropland by watershed management (tile, surface drains, open ditch or pumps) and channel improvement. First cost: $0.1 million	Suggested devices: Draining 7000 acres of cropland and 2000 acres of forestland by watershed management and channel improvement. First cost: $0.4 million	Suggested devices: Draining 8000 acres of cropland and 7000 acres of forestland by watershed management and channel improvement. First cost: $0.3 million

NAR Area 9 - Summary Table 2 (Cont'd)

1980	2000	2020
15. Erosion Control		
Suggested devices: Erosion control on 73,000 acres by watershed management (diversion, waterways, strip cropping, cover cropping, etc.), reducing sediment load by 17,000 cubic yards annually. First cost: $4.3 million Annual cost: $0.3 million	Suggested devices: Erosion control on 189,000 acres by watershed management, reducing sediment load by 63,000 cubic yards annually. First cost: $13.6 million Annual cost: $ 0.9 million	Suggested devices: Erosion control on 281,000 acres by watershed management, reducing sediment load by 133,000 cubic yards annually. First cost: $21.0 million Annual cost: $ 1.3 million
16. Health Aspects		
Suggested devices: Insect control; facilities for recreation; and a water hygiene laboratory.	Suggested devices: Insect control and facilities for recreation.	Suggested devices: Insect control and facilities for recreation.
17. Visual and Cultural Environment		
Suggested improvements: Protection of 1,000 square miles of unique landscape and coastline; protection of cultural and historic sites in urban areas and environment· improvement of water quality: and use of river design potential.	Suggested improvements: Improvement of accessibility within area and improvement of quality and absorptive capacity of 2,100 sq. miles of forest landscape.	Suggested improvement: Creation of 200 sq. miles of town/farm landscape.
18. Legal Measures		
Suggested measures: Establishment of interstate fishing compact within NAR area; establishment of State control of wildlife resources and anadromous and shellfish fisheries; and revision of planning and zoning laws.		

NAR Area 9 - Summary Table 3

1980	2000	2020
1. Municipal and Industrial Water Supply		
Demand 730 mgd, 160 mgd increment over present. Suggested devices: 160,000 AF storage; 40 mgd wells; 70 mgd diversion; river intakes; 80 mgd treatment plants; tunnels and pipelines. First cost: Surface water $69.0 million Ground water 4.0 million Total $73.0 million	Demand 990 mgd, 260 mgd increment over year 1980. Suggested devices: 35,000 AF storage, 70 mgd wells; 120 mgd diversion; river intakes; 75 mgd treatment plants; tunnels and pipelines. First cost: Surface water $75.0 million Ground water 7.0 million Total $82.0 million	Demand 1370 mgd, 380 mgd increment over year 2000. Suggested devices: 23,000 AF storage: 120 mgd wells; river intakes; 180 mgd treatment plants; tunnels and pipelines; and 100 mgd diversion from other areas. First cost: Surface water $66.0 million Ground water 12.0 million $78.0 million
2. & 5. Self-Supplied Industrial Process and Cooling Water		
Demand 230 mgd, 90 mgd increment over present. Suggested devices: River intakes and 15 mgd wells. First cost: $1.5 million for wells.	Demand 340 mgd, 110 mgd increment over year 1980. Suggested devices: River intakes and 20 mgd wells. First cost: $2.0 million for wells.	Demand 500 mgd, 160 mgd increment over year 2000. Suggested devices: River intakes and 35 mgd wells. First cost: $3.5 million for wells.
3. Rural Domestic and Livestock Water Supply		
Demand 50 mgd, 26 mgd over present. Suggested devices: 26 mgd wells. First cost: $2.6 million	Demand 95 mgd, 45 mgd over year 1980. Suggested devices: 45 mgd wells. First cost: $4.5 million	Demand 117 mgd, 22 mgd over year 2000. Suggested devices: 22 mgd wells. First cost: $2.2 million
4. Irrigation Water Supply		
Yearly demand 54,000 AF, 39,000 AF increment over present. Suggested devices: 16,000 AF storage and 23,000 AF wells and streams. First cost: $15.1 million Annual cost: $ 3.2 million	Yearly demand 69,000 AF, 17,000 increment over year 1980. Suggested devices: 8,500 AF storage and 8,500 AF wells and streams. First cost: $19.1 million Annual cost: $ 4.1 million	Yearly demand 89,000 AF, 22,000 increment over year 2000. Suggested devices: 13,000 AF storage and 9,000 AF wells and streams. First cost: $12.2 million Annual cost: $ 1.3 million

NAR Area 9 - Summary Table 3 (Cont'd)

1980	2000	2020
6. Power Cooling Water		
Demand 210 cfs consumptive water from the coastal waters for 13,000 mw total power installation with cooling towers.	Demand 450 cfs consumptive water from the coastal waters for 30,000 mw total power installation with cooling towers.	Demand 1,500 cfs consumptive water from the coastal waters for 98,000 mw total power installation with cooling towers.
7. Hydroelectric Power		
Hydroelectric power generation not anticipated.	Hydroelectric power generation not anticipated.	Hydroelectric power generation not anticipated.
8. Navigation		
Annual tonnage 61.0 million, 18.0 million over present. Suggested devices: Deepening and widening of certain channels within the Port of Boston. First cost: $47.0 million	Annual tonnage 96.0 million, 35.0 million over year 1980. Suggested devices: Further deepening and widening of channels within the Port of Boston; deepening and widening of Salem Harbor channel; and deepening of Providence River and Harbor channel, New Bedford Harbor channel, and Cape Cod Canal. First cost: $112.0 million	Annual tonnage 150.0 million, 54.0 million over year 2000. Suggested devices: Further deepening of Port of Boston channels, Providence River and Harbor channel, and Cape Cod Canal. First cost: $172.0 million
9. Recreation		
Total water-oriented recreation days 94.0 million. Demand: Water surface acres by minimum unit size: >500:105,000 >200:30,000 >10:5,000 Stream miles 310; Beach acres 700 or swimming pool sq. ft. 14.0 million; Land acres 42,000. Possible devices: Expansion of existing sites; utilization of untapped resources; new reservoirs; changes in design loads of existing facilities; conversion of existing projects to include recreation; improvement of transportation system. May also include navigation improvements and beach erosion control. Definition of need for in-depth studies to determine adequacy of existing water quality classification system, and determination of feasibility of setting a minimum classification allowing for primary contact recreation on all waters on Cape Cod.	Incremental water-oriented recreation days 56.0 million. Incremental demand: Water surface acres by minimum size: >500:54,000 >200:15,000 >10:2,600; Stream miles 94; Beach acres 220 or swimming pool sq. ft. 4.3 million; Land acres 14,000. Possible devices: Same as for 1980.	Incremental water-oriented recreation days 63.0 million. Incremental demand: Water surface acres by minimum size: >500:71,000 >200:22,000 >10:2,800; Stream miles 50; Beach acres 105 or swimming pool sq. ft. 2.1 million; Land acres 13,000. Possible devices: Same as for 1980.

	1980	2000	2020
10. Fish and Wildlife			
	Fishing: 9.7 million man days, 1.8 million over present. Wildlife: 1.7 million man days, 0.2 million over present. Suggested devices: Fishing: 430 acres of freshwater access; 140 acres of saltwater access; and maintaining existing habitat and water quality. Wildlife: Maintaining habitat consistent with land use projections and providing access; hunting regulations that allow maximum sustained yield of big game; hunting regulations for small game; and maintaining waterfowl habitat at 1965 level. First cost: Freshwater access $4.1 million Saltwater access 1.4 million Total $5.5 million Annual cost: Freshwater access $0.7 million Saltwater access 0.2 million Total $0.9 million	Fishing: 12.6 million man days, 3.0 million over year 1980. Wildlife: 2.0 million man days, 0.3 million over year 1980. Suggested devices: Fishing: Opening single purpose water supply reservoirs and providing access to private lakes; 170 acres of freshwater access; and 240 acres of saltwater access. Wildlife: Same as for 1980 but maintaining small game habitat at year 2000 level. First cost: Freshwater access $1.9 million Saltwater access 2.8 million Total $4.7 million Annual cost: Freshwater access $0.3 million Saltwater access 0.4 million Total $0.7 million	Fishing: 16.0 million man days, 3.4 million over year 2000. Wildlife: 2.4 million man days, 0.4 million over year 2000. Suggested devices: Fishing: 20,000 surface acres of impoundments; 200 acres of freshwater access; and 280 acres of saltwater access. Wildlife: Same as for 1980 but maintaining small game habitat at year 2000 level. First cost: Freshwater access $1.6 million Saltwater access 2.4 million Total $4.0 million Annual cost: Freshwater access $0.3 million Saltwater access 0.4 million Total $0.7 million
11. Solid Waste Disposal			
	Annual quantity of solid waste 6,700 AF, 3,700 AF over present. 6,000 acres required for sanitary fill to 1980.	Annual quantity of solid waste 11,300 AF, 4,600 AF over year 1980. 26,000 acres required for sanitary fill between 1980 and 2000.	Annual quantity of solid waste 17,000 AF, 5,700 AF over year 2000. 40,000 acres required for sanitary fill between 2000 and 2020.

1980	2000	2020
12. Liquid Waste Disposal		
Total untreated waste load 11.1 million PE. Suggested devices: Secondary treatment (85% Removal), reducing waste discharge to 1.7 million PE. First cost: $775 million	Total untreated waste load 16.3 million PE. Suggested devices: Secondary treatment (90% Removal), reducing waste discharge to 1.6 million PE: advance waste treatment at specific locations (95% Removal), further reducing waste discharge to 0.8 million, or low flow augmentation in lieu of advance waste treatment. First cost: Secondary treatment $1,142 million Advance waste treatment 98 million Total $1,240 million	Total untreated waste load 25.0 million PE. Suggested devices: Secondary Treatment (90% Removal), reducing waste discharge to 2.5 million PE: advance waste treatment (95% Removal), further reducing waste discharge to 1.5 million PE, or low flow augmentation in lieu of advance waste treatment. First cost: Secondary treatment $1,745 million Advance waste treatment 150 million Total $1,895 million
13. Flood Control		
Main stem: Total average annual flood damage $11.1 million, $4.0 million over present. Suggested devices: Flood plain management, reducing average annual damage by $4.4 million. Upstream watersheds: Total average annual flood damage $6.5 million, $2.5 million over present. Suggested devices: 63 small dams impounding 71,000 AF of flood flow, reducing total average annual damage by $1.0 million. First cost: $14.0 million Annual cost: $ 0.8 million	Main stem: Total average annual flood damage $21.2 million, $10.1 million over year 1980. Suggested devices: Flood plain management, reducing total average annual damage by $13.5 million. Upstream watersheds: Total average annual damage $12.2 million, $5.7 million over year 1980. Suggested devices: No additional improvements, but total average annual damage reduced by $2.0 million by 1980 improvements.	Main stem: Total average annual damage $42.6 million, $21.4 million over year 2000. Suggested devices: Flood plain management, reducing total average annual damage by $33.3 million. Upstream watersheds: Total average annual damage $24.0 million, $11.8 million over year 2000. Suggested devices: No additional improvements, but total average annual damage reduced by $5.0 million by 1980 improvements.
14. Drainage		
Suggested devices: Draining 3,000 acres of cropland and 2,000 acres of forestland by watershed management (title, surface drains, open ditch or pumps) and channel improvement. First cost: $0.3 million	Suggested devices: Draining 6,000 acres of cropland and 7,000 acres of forestland by watershed management and channel improvement. First cost: $0.6 million	Suggested devices: Draining 1,000 acres of cropland and 21,000 acres of forestland by watershed management and channel improvement. First cost: $0.7 million

NAR Area 9 - Summary Table 3 (Cont'd)

1980	2000	2020
15. Erosion Control		
Suggested devices: Erosion control on 95,000 acres by watershed management (diversion, waterways, strip cropping, cover cropping, etc.), reducing sediment load by 21,000 cubic yards annually. First cost: $5.5 million Annual cost: $0.4 million	Suggested devices: Erosion control on 240,000 acres by watershed management, reducing sediment load by 76,000 cubic yards annually. First cost: $17.2 million Annual cost: $ 1.1 million	Suggested devices: Erosion control on 353,000 acres by watershed management, reducing sediment load by 161,000 cubic yards annually. First cost: $20.3 million Annual cost: $ 1.6 million
16. Health Aspects		
Suggested devices: Insect control: facilities for recreation· and a water hygiene laboratory.	Suggested devices: Insect control and facilities for recreation.	Suggested devices: Insect control and facilities for recreation.
17. Visual and Cultural Environment		
Suggested improvements: Protection of 1,000 sq. mi. of unique landscape and coastline and concentrations of cultural and historic sites in urban improvements; improvement of water quality and accessibility; use of river design potential· provision of ammenities for urban areas: and improvement of quality and absorptive capacity of 2,100 sq. mi. of forest landscape.		Suggested improvement: Creation of 200 sq. mi. of town/farm landscape.
18. Legal Measures		
Suggested measures: Establishment of interstate fishing compact within NAR area; establishment of State control of wildlife resources and anadromous and shellfish fisheries; and revision of planning and zoning laws.		

CHAPTER 4

SECOND STAGE OF PLAN FORMULATION

DEPARTMENT OF THE ARMY
NORTH ATLANTIC DIVISION, CORPS OF ENGINEERS
90 CHURCH STREET
NEW YORK, N. Y. 10007

IN REPLY REFER TO

13 February 1970

MEMORANDUM 70-14
TO MEMBERS OF THE COORDINATING COMMITTEE
NORTH ATLANTIC REGIONAL WATER RESOURCES STUDY

Area 9 planning materials are inclosed as the first output for second round plan formulation. Comments on this package should be received by the NAR Study Group by 20 April 1970. Your comments should first be based upon a review of the inclosed basic data and a review of the interpretations of that data; second, it should make an evaluation of the applicability of the suggested devices to your functional or geographical area; and third, it should discuss your recommendations which will enable the plan formulation work group to develop a recommended plan. Similar packages for all basins will follow as will packages of basin, state and commission outputs from the water demand, water supply and land allocation models. These models and the output for second round plan formulation will be discussed at the 10th Coordinating Committee--Board of Consultants Meeting in Washington, D. C. on the 25th and 26th of February.

Each area package represents the first phase of the second round plan formulation for that area and will follow the format of the inclosed area 9. This format includes the latest revisions of first round plan formulation data, taking into account the comments received during that time, together with two new tables explained here. Formats of the old tables have also been revised for ease in their use. Information in these packages provides essential input and background to the three planning models (water demand, water supply and land allocation) which are central to the second round of plan formulation.

Provided as an introduction to the area package are a map of the area and a general description of the economic, demographic and physical nature of the area. Following this are four pages summarizing the basic plan formulation data of the package and then the pages of basic data, presented last to facilitate the use of the total package.

There are two types of basic data tables in this last part of the package. The first set of tables has the demand estimates for water in the area by each need. Included here are the devices most likely to be used in satisfying these levels of demand along with the costs of these devices. All of this information is given by the three objectives and the three benchmark years and has been revised from the first round of plan formulation.

The second set of basic tables are new but have a predecessor in the needs/sources/devices matrix, first introduced in Memorandum 69-2, the minutes of the sixth meeting of the Coordinating Committee (Appendix F). These tables, in light of the suggested water demands and devices for the area, give estimates of the non-monetary benefits and costs from the physical interactions that occur when each of the needs of the area is met. These estimates require one table for each of the 17 needs for each area. On each table for a need, there are listed the principal beneficial and detrimental physical interactions between the devices of that one need and the devices of every other need. Non-monetary benefit and cost judgements are made on a scale ranging from zero to high, to show the relative benefits or costs to other needs when one need is fulfilled. This information, offered now for review, will be used to evaluate the inputs to and the outputs of the planning models.

Based on these two sets of basic data are the summary tables which appear in front of them. Immediately in front of the data tables are three summary tables showing water availability, water demands (withdrawal and reuse) and water balances. The formats and data of these tables have also been revised since the first round plan formulation.

In front of these three pages of summary tables is the fourth page of new summary tables. A narrative summary of the area is first given on this page showing the water demands and supplies as seen at this time. Second, a table of the monetary costs of the suggested devices is shown, given by objectives and benchmark years. Finally, a table is presented summarizing the non-monetary benefits and costs as estimated for the interactions of all the needs of the area. These summary tables should all be reviewed, as they will also serve as background and sources of evaluation for the inputs to an the outputs of the planning model.

The non-monetary tables do not list interactions specifically by benchmark years. This facilitates discussion in terms of generally similar sets of interactions over the planning period for water resources, without ruling out important comments on and consideration of changes in technology.

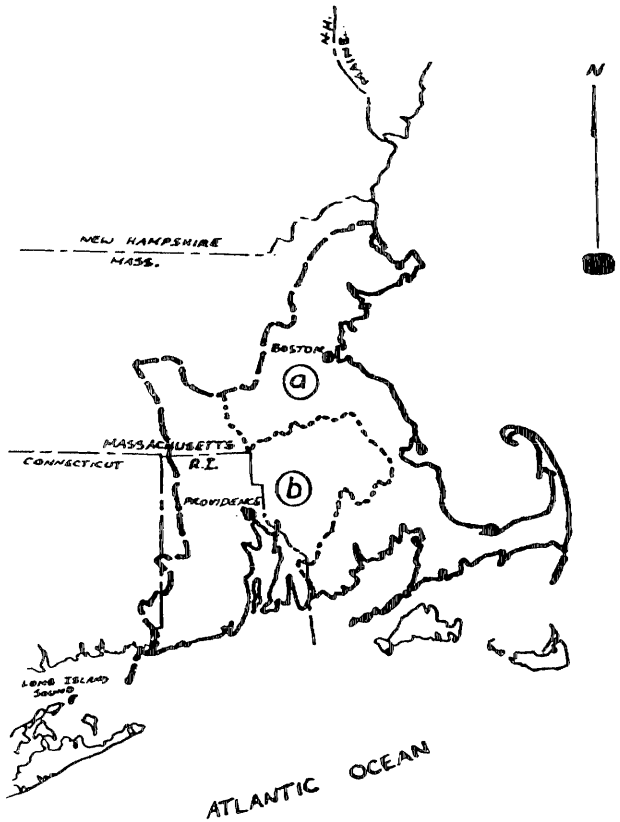
Note that the figures given in the tables represented by the inclosure are not final estimates of the three alternative programs to be presented but are input and background to the three planning models. The estimates for the three alternative programs that will constitute the culmination of the second round of plan formulation will be presented largely in terms of outputs from the planning models.

HARRY E. SCHWARZ
Executive Secretary

1 Incl
Second Round of
Formulation Package

PLANNING MATERIALS
FROM SECOND STAGE OF
PLAN FORMULATION

Area 9



AREA 9

INTRODUCTION

Area 9 encompasses the Narragansett Bay drainage, the Pawtucket River, and the Atlantic coastal area from the New Hampshire-Mass. state line to the Rhode Island-Conn. line. It includes the port of Boston, Salem Harbor channel, and the Providence River Harbor channel. The area is primarily a coastal plain with numerous good harbors. The extensive coastal area provides many resort and recreation sites including Cape Cod, Nantucket Island and Newport. The topography varies from coastline to rolling hills. Sub-area 9a consists of the Massachusetts coastal area drainage and sub-area 9b encompasses the Narragansett Bay and Pawtucket River drainage.

Area 9 is the commercial, industrial, financial and educational center of New England. It is predominantly urban, with the highest population density in New England. It is an important center of medical and related research.

The population of the area was 4.7 million in 1960 and is projected to increase to 8.7 million by the year 2020. Population density in Area 9 was 1,077 people per square mile in 1960. Suffolk County Mass. had the greatest density with 14,207 people per square mile, and Rhode Island, Bristol and Providence counties were the most heavily populated with 1,492 and 1,369 people per square mile, respectively.

The economic activities of Area 9 are centered in five Metropolitan State Economic Areas; Boston-Lowell-Lawrence, Brockton, Fall River-New Bedford, Worcester, Providence-Pawtucket-Warwick. Personal income is projected to increase to $104.2 billion by 2020. Personal income per capita was slightly in excess of the U. S. average in 1960 and is projected to continue this relative position.

Employment in 1960 was 1.7 million and is projected to increase to 3.3 million in the year 2020; 602,000 were employed in manufacturing in 1960, and the number employed was expected to increase modestly to 717,000 by the year 2020.

Among water using manufacturing industries, an increase in employment was projected for chemicals and allied products, paper and allied products and primary metals, a decline in employment for food and kindred products, textile mill products and petroleum refining, with the largest decline in the latter two industries.

The major increase in employment in Area 9 is projected for the category "other employment" which is expected to increase from 1.05 million to 2.5 million, by 2020.

ENVIRONMENTAL QUALITY: greatest non-monetary benefits for this objective can be obtained by emphasizing the demands for (9) Fish and Wildlife, (11) Liquid Waste Disposal, (12) Flood Control, (13) Drainage, (14) Erosion and (16) Visual and Cultural needs. Visual and Cultural (16) needs show the highest beneficial effects. Fulfilling these needs causes moderate non-monetary costs in (8) Recreation, (9) Fish and Wildlife and (16) Visual and Cultural needs. Overall non-monetary benefits from fulfilling the EQ objective are high and overall non-monetary costs are moderate.

NATIONAL EFFICIENCY: greatest non-monetary benefits for this objective can be obtained by emphasizing demands for (11) Liquid Waste Disposal and (16) Visual and Cultural needs. Fulfilling these needs causes only low non-monetary costs. Overall non-monetary benefits from fulfilling the NE objective are low, as are non-monetary costs.

REGIONAL DEVELOPMENT: greatest non-monetary benefits for this objective can be obtained by emphasizing demands for (8) Recreation, (9) Fish and Wildlife, (11) Liquid Waste Disposal and (16) Visual and Cultural needs. Visual and Cultural (16) needs show the highest beneficial effects. Fulfilling these needs causes moderate non-monetary costs for (9) Fish and Wildlife, (12) Flood Control and (16) Visual and Cultural needs. Overall non-monetary benefits from fulfilling the RD objective are moderate and overall non-monetary costs are low.

	MONETARY DEVICE COSTS 2/								
	1980			2000			2020		
	EQ	NE	RD	EQ	NE	RD	EQ	NE	RD
1. M. and I.	73.0	73.0	73.0	82.0	82.0	82.0	78.0	78.0	78.0
2. Ind., Self-Sup.	1.5	1.5	1.5	2.0	2.0	2.0	3.5	3.5	3.5
3. Rural Water	0.3	0.3	0.3	<0.1	<0.1	<0.1	0.0	0.0	0.0
4. Irrigation	16.3	14.9	16.0	16.5	13.6	16.[illegible]	19.5	17.9	17.7
5. Power Cooling 3/	0.0	0.0	0.0	73.0	0.0	18.0	144.[illegible]	0.0	0.0
6. Hydroelectric	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7. Navigation	12.0	47.0	47.0	69.3	112.0	112.0	12.6	172.0	172.0
8. Recreation									
9. Fish & Wild L.	3.1	3.1	3.1	5.2	5.2	5.2	6.1	6.1	6.1
10. Solid Waste									
11. Liquid Waste 4/	198.0	198.0	198.0	552.0	552.0	552.[illegible]	841.0	841.0	841.0
12. Flood Control	14.0	5.2	14.0	0.0	8.8	0.0	0.0	0.0	0.0
13. Drainage	0.6	0.4	0.6	1.3	1.0	1.3	0.5	0.5	0.6
14. Erosion	11.7	9.0	11.6	28.9	22.8	28.8	41.6	33.1	41.5
15. Health									
16. Visual & Cult'l									
17. Legal									
Totals 1/	330	352	365	830	799	818	1147	1152	1160

1/ Incomplete as only known costs are included.
2/ In millions
3/ Additional costs incurred for environmental or regional development reasons.
4/ Does not include costs of combined and stormwater and nutrient control under environmental quality.

NON-MONETARY INTERACTIONS					
Benefits			Costs		
EQ	NE	RD	EQ	NE	RD
•	•	•	•		
	•	•	•		
●	•	•	•	•	•
			•		
•			•		
●	•	●	●	•	•
●	•	●	●	•	●
•					
●	●	●	•	•	•
●	•	•	•	•	●
●	•	•	•		
●	•	•			
•	•	•			
●	●	●	●	•	●
●	•	●	●	•	•

☐ INSIGNIFICANT
• SIGNIFICANT
● VERY SIGNIFICANT
● EXTREMELY SIGNIFICANT

Area 9

SUMMARY OF WATER DEMANDS (C.F.S.)

Fresh Water Withdrawals	Environmental Quality 1980	Environmental Quality 2000	Environmental Quality 2020	National Efficiency 1980	National Efficiency 2000	National Efficiency 2020	Regional Development 1980	Regional Development 2000	Regional Development 2020
Public M & I	1132	1520	2100	1132	1520	2100	1132	1520	2100
Self-Supp. Ind.	422	629	906	422	629	906	422	629	906
Rural W. S.	19	20	8	19	20	8	19	20	8
Irrigation [1]	430	600	820	375	425	577	420	595	743
Power Cooling	–	–	–	–	–	–	–	–	–
Total	2003	2769	3834	1948	2594	3591	1993	2764	3757
Adjusted Total [2]	1419	1939	2685	1392	1851	2564	1414	1937	2647
In-Stream Needs									
Hydroelectric	–	–	–	–	–	–	–	–	–
Navigation	–	–	–	–	–	–	–	–	–
Recreation	[3]	[3]	[3]	[3]	[3]	[3]	[3]	[3]	[3]
Fish and Wildlife [4]	1000	1000	1000	1000	1000	1000	1000	1000	1000
Waste Discharge [5]	1290	1290	1940	1290	1290	1940	1290	1290	1940
Critical Need [6]	1290	1290	1940	1290	1290	1940	1290	1290	1940

Reuse Factors

E.Q.	1980	2000	2020	
M & I	1.1	1.1	1.1	a)
Ind.	2.5	2.5	2.5	b)
Rural	3.5	3.5	3.5	c)
Irr.	2.0	2.0	2.0	d)
P.C.	–	–	–	e)
N.E.				
M & I	1.1	1.1	1.1	a)
Ind.	2.5	2.5	2.5	b)
Rural	3.5	3.5	3.5	c)
Irr.	2.0	2.0	2.0	d)
P.C.	–	–	–	e)
R.D.				
M & I	1.1	1.1	1.1	a)
Ind.	2.5	2.5	2.5	b)
Rural	3.5	3.5	3.5	c)
Irr.	2.0	2.0	2.0	d)
P.C.	–	–	–	e)

1) Peak 30-day requirement during irrigation season.
2) Based on application of reuse factors to total withdrawals.
3) Optimum activity in selected reaches would require maintenance of May mean monthly flows.
4) Average base flow requirement shown. Add'l. needs likely in selected reaches.
5) Min. exist. flow S.I.O.10, 7-day = 1,290 cfs. 50% increase in 2020 would be in lieu of AWTR.
6) Exist. hydroelectric operation should permit maintenance of flow through weekends.

a) Limited by location & device.
b) Average for area.
c) Mostly ground water, allow for loss.
d) Seasonal; reduce to effective demand on sources. All loss.
e) No fresh demand.

Note: This material on Summary of Water Demands, Withdrawal and In-stream Resource Balances and Water Resources Availability was prepared in complete form only for Basin 9. The experience gained in preparing this set was used in preparing the supply model and later versions of the area plans produced in Stage 3 of the planning process.

The withdrawal and in-stream balances indicate significant resource deficiences within Area 9 for all objectives in 2020. Due to the larger irrigation requirement, the deficiency is over 20% greater for environmental quality than for national efficiency, with regional development in an intermediate position. As indicated on the water resources availability page, a considerable amount of rural ground water (which could be considered mostly additive to the developable resource) is available. However, it is doubtful that this could be more than a partial answer to satisfying the deficiences which exist mostly in the more urban areas.

It should be noted that somewhat less than the overall developable resource indicated for withdrawal use would actually be utilized. This is due to the difficulty of supplying concentrated urban areas with a resource that is largely scattered in small streams. Accordingly, importation from other areas, which is indicated by the area balance, could be larger than the Area 9 resource deficiency. Imports would be mostly to Sub-area 9a where additional major reservoir development is not feasible.

From similar balances for Sub-areas 9a and 9b, it is noted that about 80% of the area deficiency for withdrawal occurs in Sub-area 9a. Again the deficiency is about 20% larger for environmental quality than for national efficiency. However, overall in-stream needs in Sub-area 9a, which would be controlled by waste discharge requirements necessary in lieu of advanced waste treatment, compare favorably with the prospective in-stream resource.

In Sub-area 9b the reverse situation prevails. The in-stream need in 2020, again controlled by waste discharge requirements, is significantly (about 400 cfs) greater than the developable resource. There is little variation between objectives. Since the withdrawal deficiency in 2020 is only about 1/3 as great as the in-stream deficiency, its satisfaction would not solve the in-stream problem.

WITHDRAWAL AND IN-STREAM RESOURCE BALANCES
(all items in c.f.s.)

	1980	2000	2020
ENVIRONMENTAL QUALITY Withdrawal	1419	1939	2685
Developable Resource	2180	2180	2180
Excess (+) or Deficient (-) Resource	+761	+241	-505
ENVIRONMENTAL QUALITY In-Stream Need	1290	1290	1940
Consumptive Loss	200	355	560
Developable Resource [2]	1925	1925	1925
Excess (+) or Deficient (-) Resource	+435	+280	-575
NATIONAL EFFICIENCY Withdrawal	1392	1851	2564
Developable Resource	2180	2180	2180
Excess (+) or Deficient (-) Resource	+788	+329	-384
NATIONAL EFFICIENCY In-Stream Need	1290	1290	1940
Consumptive Loss	175	265	435
Developable Resource [2]	1925	1925	1925
Excess (+) or Deficient (-) Resource	+460	+370	-450
REGIONAL DEVELOPMENT Withdrawal	1414	1937	2647
Developable Resource	2180	2180	2180
Excess (+) or Deficient (-) Resource	+766	+243	-467
REGIONAL DEVELOPMENT In-Stream Need	1290	1290	1940
Consumptive Loss	200	355	620
Developable Resource [3]	1925	1925	1925
Excess (+) or Deficient (-) Resource	+435	+280	-535

[1] Assumed developable resource (S.I.01) minus adjusted withdrawal.
[2] Assume that only ½ of add'l resource developed would be conveyed thru natural channels and available for in-stream use. ½(1290 + 2560) = 1925 cfs.
[3] Assumed developable resource (S.I.10) minus sum of in-stream need and withdrawal consumptive loss.

See note on page 88.

WATER RESOURCES AVAILABILITY
(all items in c.f.s.)

Average Annual Runoff	8200
Existing Minimum Streamflow [1]	
Shortage index 0.01 (approx. 7-day flow)	1065
Shortage index 0.10 (approx. 7-day flow)	1290
Major Reservoir Potential [2]	
Practical development streamflow, (SI=.01)	1690
Practical development streamflow, (SI=.10)	2050
Upstream Reservoir Potential	
Practical gross at-site yield for 219,700 A.F. at 87 sites (1% chance of shortage)	442
Ground Water Potential	
Practical development (municipal, industrial)	590
Practical development (rural)	1175
Extra storage equivalent	small
Assumed Developable Resource [3]	
Shortage index 0.01	2180
Shortage index 0.10	2560

[1] Excludes present yield of M.D.C. reservoir system.
[2] Includes present M.D.C. yield plus approx. 100,000 A.F. of additional storage.
[3] Based on practical development streamflow with major reservoirs plus incremental net yield of 1/2 the upstream reservoirs plus ground water equal to maximum rural (irrigation + rural w.s.) need minus an allowance for estimated overlap in yield. (1690 + 180 + 418) - 4.5% = 2180 cfs.

See note on page 88.

Area 9
Need Municipal and Industrial Water Supply

OBJECTIVE	BENCH MARK YEARS	MUNICIPAL AND INDUSTRIAL DEMAND: Water Supply mgd	Increment over previous BMY mgd	POSSIBLE DEVICES: Well mgd	River intake	Lake intake	Storage 1000 AF	Treatment plant mgd	Diversion, interbasin mgd	Diversion, intrabasin mgd	Tunnel	Pipeline	Pumping station	Aqueduct	$ Million First Cost: Surface	Ground	Total
	Present	570	–														
EQ	1980	730	160	40	×		160	60	70		×	×			69	4	73.0
	2000	990	260	70	×		30	88	120		×	×			75	7	82.0
	2020	1,370	380	120	×		23	185	100		×	×			66	12	78.0
NE	1980	730	160	40	×		160	60	70		×	×			69	4	73.0
	2000	990	260	70	×		30	88	120		×	×			75	7	82.0
	2020	1,370	380	120	×		23	185	100		×	×			66	12	78.0
RD	1980	730	160	40	×		160	60	70		×	×			69	4	73.0
	2000	990	260	70	×		30	88	120		×	×			75	7	82.0
	2020	1,370	380	120	×		23	185	100		×	×			66	12	78.0

Area 9
Need Self-Supplied Industrial Process and Cooling Water

INDUSTRIAL PROCESS AND COOLING DEMAND				POSSIBLE DEVICES						
OBJECTIVE	BENCH MARK YEARS	Water Supply mgd	Increment Over Previous BMY mgd	River intake	Lake intake	Wells and	Pumping facilities	Cooling towers		$ Million First Cost
	Present	140	—							
EQ	1980	230	90	x		15				1.5
	2000	340	110	x		20				2.0
	2020	500	160	x		35				3.5
NE	1980	230	90	x		15				1.5
	2000	340	110	x		20				2.0
	2020	500	160	x		35				3.5
RD	1980	230	90	x		15				1.5
	2000	340	110	x		20				2.0
	2020	500	160	x		35				3.5

Area 9
Need Irrigation Water Supply

IRRIGATION DEMAND						POSSIBLE DEVICES			$ MILLION Cost			
									First		Annual	
OBJECTIVE	BENCH MARK YEARS	Agr. Water Supply AFY x1000	Agr. Increment Over Previous BMY AFY x1000	Non. Ag. Water Supply AFY x1000	Non. Ag. Increment Over Previous BMY AFY x1000	Storage	Wells	River Intake	Agri.	Non. Agri.	Ag.	Non. Ag.
	Present	11.8		9.9								
EQ	1980	37.1	25.3	27.3	17.4	X	X	X	2.2	14.1	0.6	1.5
	2000	46.0	8.9	44.1	16.8	X	X	X	3.4	13.1	0.8	1.4
	2020	57.7	11.7	65.3	21.2	X	X	X	2.0	17.5	0.5	1.8
NE	1980	30.7	18.9	25.5	15.6	X	X	X	1.2	13.7	0.3	1.4
	2000	21.2	-9.5	42.6	17.1	X	X	X	-	13.6	-	1.4
	2020	21.2	0	65.3	22.7	X	X	X	-	17.9	-	1.9
RD	1980	37.1	25.3	25.9	16.0	X	X	X	2.2	13.8	0.6	1.4
	2000	46.0	8.9	43.3	17.4	X	X	X	3.4	13.2	0.8	1.4
	2020	46.0	0	65.3	22.0	X	X	X	-	17.7	-	1.9

Area 9
Need Rural Domestic and Livestock Water Supply

RURAL WATER SUPPLY DEMAND					POSSIBLE DEVICES		
OBJECTIVE	BENCH MARK YEARS	Water Supply mgd	Increment Over Previous BMY mgd		Wells	Cost (1000 $) First	Cost (1000 $) Annual
	Present	9.6					
EQ	1980	12.5	2.9		X	290	
	2000	12.8	0.3		X	30	
	2020	5.3	-7.5		X		
NE	1980	12.5	2.9		X	290	
	2000	12.8	0.3		X	30	
	2020	5.3	-7.5		X		
RD	1980	12.5	2.9		X	290	
	2000	12.8	0.3		X	30	
	2020	5.3	-7.5		X		

Area 9
Need Power Cooling Water

OBJECTIVE	BENCH MARK YEARS	Power mw	Condenser Flow cfs	Withdrawls Saline cfs	Withdrawls Brackish cfs	Withdrawls Fresh cfs	Consumption Brackish cfs	Consumption Fresh cfs	Cooling tower	River intake	Lake intake	Estuarine intake	Ocean intake	Non-condensing facilities	Incremental Total Capacity Cost ($ 1973)
	Present	4600	4700	4700											
EQ	1980	10,300	11,800	11,800									X		0
	2000	28,300	28,800	27,900	900		12					X	X	X	73,000
	2020	55,000	44,100	42,400	1700		23					X	X	X	144,000
NE	1980	10,300	11,800	11,800									X		0
	2000	30,600	31,000	31,000			•						X		0
	2020	62,200	49,600	49,600									X		0
RD	1980	10,300	11,800	11,800									X		0
	2000	27,600	28,000	26,400	1600		20					X	X		18,000
	2020	59,200	46,600	42,400	4200		47					X	X		0

POWER COOLING DEMAND

POSSIBLE DEVICES

Area 9
Need Navigation

OBJECTIVE	BENCH MARK YEARS	NAVIGATION DEMAND: Transportation Annual Tonnage Million Tons	NAVIGATION DEMAND: Increment over Previous BMY Million Tons	FACILITIES ANNUAL EXPENDITURE $ MILLION Recreational Boating	POSSIBLE DEVICES: Channel improvement	Harbor improvement	Lightering	Diversion of cargo	Rehabilitation of locks	Removal of obstructions	Offshore facilities	Navigation aids	Breakwater & jetty construction	Recreational harbors		$ MILLION First Cost
	Present	50		0.2												
EQ	1980	61	11	0.4	X	X	X	X		X	X	X	X	X		12
	2000	100	39	0.4	X	X	X	X		X	X	X	X	X		69.3
	2020	165	65	0.4	X	X	X	X		X	X	X	X	X		12.6
NE	1980	61	11		X	X				X	X	X	X			47
	2000	100	39		X	X				X	X	X	X			112
	2020	165	65		X	X				X	X	X	X			172
RD	1980	61	11		X	X				X	X	X	X			47
	2000	100	39		X	X				X	X	X	X			112
	2020	165	65		X	X				X	X	X	X			172

Area 9
Need Recreation

		WATER ORIENTED RECREATION DEMAND							POSSIBLE DEVICES										
		Recreation	Stream or Rivers	Surface acres by minimum unit size >500	>200	>10	Beach or Pool	Land for Facilities	Expand existing sites	Untapped resources	New reservoirs	Change in design load of facilities	Convert existing project to include recreation	Transportation	Navigation improvement	Beach erosion control	Cost	
OBJECTIVE	BENCH MARK YEARS	million visitor days	miles	X 1000 acres			Acres / $X 10^2$ or $X 10^6$ Sq. Ft.	X 1000 Acres									First	Annual
	Present	INCLUDED IN 1980	INCLUDED IN 1980															
EQ	1980	92	550	81.8	33.1	0	3.2 / 5.5	118	✓	✓	✓	✓	✓	✓	✓	✓		
	2000	54	191	71.3	30.2	2.6	3.9 / 6.8	41	✓	✓	✓	✓	✓	✓	✓	✓		
	2020	66	349	76.4	43.1	6.3	2.6 / 4.5	41	✓	✓	✓	✓	✓	✓	✓	✓		
NE	1980	80	128	60.1	3.8	0	0 / • •	22	✓	✓	✓	✓	✓	✓				
	2000	47	64	14.9	7.1	0	0 / 0	7.5	✓	✓	✓	✓	✓	✓				
	2020	72	115	16.4	10.1	0	0 / 0	4.3	✓	✓	✓	✓	✓	✓				
RD	1980	94	230	32.5	13.7	0	0 / 0	42	✓	✓	✓	✓	✓	✓				
	2000	56	95	33	15.1	0	0 / 0	14	✓	✓	✓	✓	✓	✓				
	2020	63	172	254	21.6	0	0 / 0	13	✓	✓	✓	✓	✓	✓				

Area 9
Need Fish and Wildlife

OBJECTIVE	BENCH MARK YEARS	Fishing Demands: Need millions man-days	Fishing Demands: Fresh surf. area in 1000 acres: lake	Fishing Demands: Fresh surf. area in 1000 acres: stream	Fishing Demands: Access in 1000 acres: Fresh	Fishing Demands: Access in 1000 acres: Salt	Fishing Demands: Access in 1000 acres: Anadromous	Fishing Demands: Piers, 1000 feet	Wildlife Demands: Need, 1000's man-days: Hunting	Wildlife Demands: Need, 1000's man-days: 4/ other	Devices for Fishing: Open exist. reservoirs	Devices for Fishing: New res. surf. area 1000 acres	Devices for Fishing: Maintain exist. habitat quality	Devices for Fishing: Meet W.Q. standards	Devices for Fishing: Land acquisition	Devices for Fishing: Remove exist. dams	Devices for Fishing: Install fishways	Devices for Fishing: Trout stocking	Devices for Fishing: Small game stocking	Devices for Wildlife: Wildlife habitat	Devices for Wildlife: Wildlife access	Devices for Wildlife: Increased management	1st Cost (Fishing Access) $ millions
	Pres.	10.0		(items below are incremental)																			
EQ	1980	2.2	2.0	0.8	0.1	0.9	1/	24	289	360	X		X	X	X			X		2/	3/		3.1
	2000	2.9	6.5	1.3	0.2	1.4	1/	41	781	552	X	3.2	X	X	X			X		2/	3/		5.2
	2020	3.3	16.8	1.5	0.2	1.7	1/	48	1,485	675	X	4.8	X	X	X			X		2/	3/		6.1
NE	1980	2.2	2.0	0.8	0.1	0.9	1/	24	289	360	X		X	X	X			X		2/	3/		3.1
	2000	2.9	6.5	1.3	0.2	1.4	1/	41	781	552	X	3.2	X	X	X			X		2/	3/		5.2
	2020	3.3	16.8	1.5	0.2	1.7	1/	48	1,485	675	X	4.8	X	X	X			X		2/	3/		6.1
RD	1980	2.2	2.0	0.8	0.1	0.9	1/	24	289	360	X		X	X	X			X		2/	3/		3.1
	2000	2.9	6.5	1.3	0.2	1.4	1/	41	781	552	X	3.2	X	X	X			X		2/	3/		5.2
	2020	3.3	16.8	1.5	0.2	1.7	1/	48	1,485	675	X	4.8	X	X	X			X		2/	3/		6.1

1/ It will probably be necessary to satisfy most of Area 9 need for anadromous fishing in other nearby NAR Areas.
2/ Maintain habitat consistent with land use projections, but maintain big game and forest small game habitat quality & quantity at 1965 levels and farm game habitat at 1980 levels. Also provide access, hunting regulations that allow maximum sustained yield, and maintain waterfowl habitat at 1965 levels. One time habitat needs: big game 3000 mi², small game 3500 mi², waterfowl 350,000 acres.
3/ Incremental access needs: 1980 - sm. game 500 mi²; 2000 - big game 100 mi², sm. game 400 mi², waterfowl 1,300 ac.; 2020 - big game 100 mi², sm. game 100 mi², waterfowl 2,200 ac.
4/ Non-consumptive needs (i.e. wildlife photography, bird watching, etc.) originating from SMA's of 1 million or more in population.

Reduce to 8½ : Pres GLOSSY

Area 9
Need Liquid Waste Disposal

OBJECTIVE	BENCH MARK YEARS	LIQUID WASTE DISPOSAL DEMAND: Million Untreated Waste PE	Million Increment over previous BMY PE	POSSIBLE DEVICES: Secondary trtmt. 85% PE reduc. w.D. 10 6 P.E.	Secondary trtmt. 90% PE reduc. w.D. 10 6 P.E.	Adv. waste treat. 95% PE reduc. w.D. 10 6 P.E.	Low flow augmentation in lieu of AWTR	Nutrient control	Stormwater discharge control	Thermo discharge control	Acid mine drainage control	Septic tank control	Separate combined sewers	Research and studies		$ Million Cost: First Secondary	First AWTR	Annual Secondary	Annual AWTR
	Present																		
EQ	1980	11.0		1.7				X	X				X			198.0			
	2000	16.2			1.6	0.8	X	X	X				X			455.0	97.0		
	2020	24.8			2.5	1.2	X	X	X				X			692.0	149.0		
NE	1980	11.0		1.7												198.0			
	2000	16.2			1.6	0.8	X							X		455.0	97.0		
	2020	24.8			2.5	1.2	X									692.0	149.0		
RD	1980	11.0		1.7												198.0			
	2000	16.2			1.6	0.8	X									455.0	97.0		
	2020	24.8			2.5	1.2	X									692.0	149.0		

Area 9
Need Flood Control

OBJECTIVE	BENCH MARK YEARS	FLOOD CONTROL DEMAND: Upstream Average annual damage Million $	Upstream Increment over previous BMY Million $	Mainstem Average annual damage Million $	Mainstem Increment over previous BMY Million $	POSSIBLE DEVICES: Upstream Flood plain management	Upstream Storage (1000 acre feet)	Upstream Small dams (No.)	Upstream Watershed management	Mainstem Flood plain management	Mainstem Storage (1000 acre feet)	Mainstem Local protection project (No.)	Mainstem Shore protection project (No.)		Avg. ann. damage reduction Million $ Upstm	Avg. ann. damage reduction Million $ Dnstm	COST $ MILLION Upstm 1st	Upstm An	Dnstm 1st	Dnstm An
	Present	4.3		7.1																
EQ	1980	6.6	2.3	11.1	4.0	X	X	X	X	X					1.2	4.4	13.8	0.8	0.2	-
	2000	12.4	5.8	21.2	10.1	X			X	X					2.3	13.5	0			
	2020	24.4	12.0	42.6	21.4	X			X	X					4.6	33.3	0			
NE	1980	6.6	2.3	11.1	4.0	X	X	X	X	X					0.5	4.4	5.0	0.3	0.2	-
	2000	12.4	5.8	21.2	10.1	X	X	X	X	X					2.3	13.5	8.8	0.5		
	2020	24.4	12.0	42.6	21.4	X			X	X					4.6	33.3	0			
RD	1980	6.6	2.3	11.1	4.0	X	X	X	X	X					1.2	4.4	138	0.8	0.2	-
	2000	12.4	5.8	21.2	10.1	X			X	X					2.3	13.5	0			
	2020	24.4	12.0	42.6	21.4	X			X	X					4.6	33.3	0			

Area 9
Need Drainage

OBJECTIVE	BENCH MARK YEARS	DRAINAGE DEMAND: Total Drainage Area Acres (1000)	DRAINAGE DEMAND: Increment Over Previous BMY Acres (1000)	DRAINAGE DEMAND: Crop Land Drainage Acres (1000)	DRAINAGE DEMAND: Forest Land Drainage Acres (1000)	DRAINAGE DEMAND: Meadow Land Drainage Acres (1000)	POSSIBLE DEVICES: Watershed Management	POSSIBLE DEVICES: Channel Improvement	Cost: First $1000	Cost: Annual $1000
	Present		19	19					1227	133
EQ	1980		9	9	0		X	X	581	63
	2000		20	19	1		X	X	1260	136
	2020		8	6	2		X	X	452	49
NE	1980		6	6	0		X	X	388	42
	2000		16	15	1		X	X	1001	108
	2020		8	6	2		X	X	452	49
RD	1980		10	9	1		X	X	614	66
	2000		21	19	2		X	X	1292	140
	2020		12	6	6		X	X	581	63

Area 4
Need Erosion Control

OBJECTIVE	BENCH MARK YEARS	EROSION CONTROL DEMAND: Erosion Control Area Acres x1000	Increment over previous BMY Acres	Sediment Load Reduction Annual CY x1000		POSSIBLE DEVICES: Watershed management	$ MILLION Cost: First	Annual
	Present							
EQ	1980	114		21		✓	11.7	0.4
	2000	257	143	76		✓	28.9	1.1
	2020	372	115	162		✓	41.6	1.6
NE	1980	86		17		✓	9	0.3
	2000	203	17	63		✓	22.8	0.9
	2020	295	92	133		✓	33.1	1.3
RD	1980	113		21		✓	11.6	0.4
	2000	255	142	76		✓	28.8	1.1
	2020	370	115	161		✓	41.5	1.6

Area 9
Need Health Aspects

		HEALTH ASPECTS DEMAND			POSSIBLE DEVICES			
OBJECTIVE	BENCH MARK YEARS	Vector Control	Pollution Control	Other	Insect Control	Legal Measures	Cost First	Cost Annual
	Present							
EQ	1980			Recreation facilities Water hygiene Lab.	X			
	2000			Recreation Facilities	X			
	2020			Recreation Facilities	X			
NE	1980			Recreation facilities water hygiene lab.	X			
	2000			Recreation facilities	X			
	2020			Recreation facilities	X			
RD	1980			Recreation facilities Water hygiene Lab.	X			
	2000			Recreation facilities	X			
	2020			Recreation facilities	X			

Area
Need Visual and Cultural Environment

		VISUAL AND CULTURAL ENVIRONMENT DEMAND									POSSIBLE DEVICES							
OBJECTIVE	BENCH MARK YEARS	Wilderness Sq. Mi.	Landscape Sq. Mi.	Water Bodies No.	Historic Sites No.	Water Quality	Ammenities Types	Coastline Mi.	Absorptive Capacity Sq. Mi.	Access	Legal		Preservation	Protection	Landscape devel.	Accessibility	Surface area AP	Cost
	Pres.																	
EQ	1980		1000		✓	✓					X		X					
	2000		200				✓		2100		X		X	X				
	2020																	
NE	1980		1000		✓	✓					X		X					
	2000								2100	✓			X	X	X			
	2020		200											X				
RD	1980		1000		✓	✓	Urban		2100	✓	X		X					
	2000																	
	2020		200								X			X				

NON-MONETARY BENEFITS AND COSTS

AREA 9
OBJECTIVE All
NEED 1-Municipal and Industrial

DEVICES

Diversion
Dams
Off Stream Storage
Wells
Recycling
Reprocessing
Treatment of water to minimum health standards

Abbreviations

EXC. S-A = Except Sub-Areas
H = high
M = medium
L = low
0 = zero or insig.

NEEDS / INTERACTIONS	BENEFITS EQ	BENEFITS NE	BENEFITS RD	EXC S-A
2. Industrial Process and Cooling:				
Partially supplied by M & I	0	L	L	
Wells provide constant temperature and quality	0	0	0	
Reuse of M & I waters	L	0	0	
3. Rural Water Supply:				
Connect to M & I system, increased efficiency, quality and fire protection	L	L	L	
4. Irrigation:				
Lawn, garden, golf course, and commercial and industrial plot watering	M	0	L	
5. Power Cooling:				
In conjunction with desalting processes	0	0	0	
6. Hydroelectric:				
Dual use	0	0	0	
7. Navigation:	0	0	0	
8. Recreation:				
Provision of more surface area for water oriented recreation	M	L	L	
9. Fish and Wildlife:				
Creation of lakes for fishing and waterfowl habitat	M	L	L	
Bird sanctuary established around wells	0	0	0	
Creation of waterfowl habitat	M	L	L	
Changing water temperature	0	0	0	
10. Solid Waste Disposal:	0	0	0	
11. Liquid Waste Discharge:				
Increased flow augmentation from groundwater sources	L	L	L	
Increased aeration due to impoundment overflows	0	0	0	
12. Flood Control:				
Increased infiltration due to lowered groundwater	0	0	0	
Complementary storage use and routing	L	M	M	

NEEDS / INTERACTIONS	COSTS EQ	COSTS NE	COSTS RD	EXC. S-A
2. Industrial Process and Cooling:				
Increased process cost and higher temperatures from discharge	0	0	0	
3. Rural Water Supply:	0	0	0	
4. Irrigation:				
Reduced well yield	0	0	0	
Base flow reduced if impoundments are withdrawal sources for M & I	0	0	0	
5. Power Cooling:				
Competitive use	0	0	0	
More cooling towers required both from increased temperatures and reduced flows if instream flow used for M & I	0	0	0	
6. Hydroelectric:				
Competitive use	0	0	0	
7. Navigation:				
Reduced flows, blocked channels	0	0	0	
8. Recreation:				
Loss of sites for swimming, boating, camping, canoeing, water skiing, etc. because of watershed and reservoir contamination, seasonal water level, fluctuation	H	M	M	
9. Fish and Wildlife:				
Disruption or loss of natural habitat from impoundments	0	0	0	
Changing water temperature	0	0	0	
Blocking anadramous access	L	0	0	
Loss of marsh habitat due to the lowering of groundwater level	0	0	0	
Changing estuary ecology due to increased or decreased flow	0	0	0	
Loss of streamflow due to consumption	0	0	0	
Increased sedimentation on spawning and shellfish areas from lowered streamflows	0	0	0	

NON-MONETARY BENEFITS AND COSTS

AREA 9
OBJECTIVE All
NEED 1-Municipal and Industrial

DEVICES	NEEDS / INTERACTIONS	BENEFITS EQ	BENEFITS NE	BENEFITS RD	EXC S-A
	13.Drainage Control:				
	Wellfields lower groundwater	O	O	O	
	14.Erosion Control:	O	O	O	
	15.Health:				
	Potable water, treatment above potable water standards (i.e. flourides, hardness addition, taste, odor, etc)	L	O	O	
	16.Visual and Cultural:				
	Creation of diversity through flatwater	L	O	O	
	Water available for lawn sprinking, street washing, fountains	L	L	L	
	With wells, landscape not disturbed	O	O	O	
	17.Legal:				
	Impoundments result in increase of local tax base	O	O	O	

NEEDS / INTERACTIONS	COSTS EQ	COSTS NE	COSTS RD	EXC. S-A
10.Solid Waste Disposal:				
Increased seepage control	O	O	O	
Competitive site use	O	O	O	
11.Liquid Waste Discharge:				
More treatment if M & I is withdrawal	O	L	L	
Reduced flow augmentation when M & I is impounded	O	O	O	
12.Flood Control:				
Competitive storage use	O	O	O	
13.Drainage Control:	O	O	O	
14.Erosion Control:	O	O	O	
15.Health:				
Sub-potable supplies	O	O	O	
Fluorides	O	O	O	
16.Visual and Cultural:				
Destruction of landscape by building of reservoirs	L	O	O	
Water level fluctuation causes loss of shoreline access and natural beauty	L	O	O	
Loss of free flowing streams	O	O	O	
17.Legal:				
Impoundments result in loss of local tax base	O	O	O	
Hardrock groundwater supply require extensive spread of wellfield possibly requiring political constraints	O	O	O	

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2

NON-MONETARY BENEFITS AND COSTS

AREA 9
OBJECTIVE All
NEED 2-Industrial Process and Cooling

DEVICES	NEEDS	INTERACTIONS	BENEFITS EQ	BENEFITS NE	BENEFITS RD	EXC S-A
Wells Dams Diversion Cooling Towers Recirculate Recharge	1. Municipal and Industrial:	Less M & I could be required if supply to industrial sectors becomes self-supplied	L	M	M	
		Reuse of Self-Supplied Industrial Process and Cooling	L	O	O	
	3. Rural Water Supply:	May connect to company system	O	O	O	
	4. Irrigation:	Reuse of Self-Supplied Industrial Process and Cooling	O	O	O	
	6. Hydroelectric:	Complementary use	O	O	O	
	7. Navigation:	Flow increased due to groundwater returns	O	O	O	
		High temperature returns maintain open water	O	O	O	
	8. Recreation:	High temperature returns maintain open water	O	O	O	
	9. Fish and Wildlife:	Creation of lakes for fishing	L	O	O	
		Changed ecology or higher productivity for certain certain species of fish due to warmer water	O	O	O	
		Increased resting areas for waterfowl due to heated discharges maintaining open water	L	O	O	
	10. Solid Waste Disposal:		O	O	O	
	11. Liquid Waste Discharge:	Flow augmentation	L	L	L	
		Increased aeration due to impoundment overflows	O	O	O	
	12. Flood Control:	Increased infiltration due to lowered groundwater	O	O	O	
		Complementary storage use and routing	O	O	O	
	13. Drainage Control:	Wellfields lower groundwater	O	O	O	
	14. Erosion Control:		O	O	O	

NEEDS	INTERACTIONS	COSTS EQ	COSTS NE	COSTS RD	EXC. S-A
1. Municipal and Industrial:	Competitive uses	O	O	O	
3. Rural Water Supply:	Competitive use	O	O	O	
4. Irrigation:	Competitive use	O	O	O	
	Base flow reduced, if impoundments are used or withdrawal for industry	O	O	O	
6. Hydroelectric:	Competitive use when consumptive	O	O	O	
7. Navigation:	Reduced flow due to consumptive use	O	O	O	
8. Recreation:	Competitive use of sites	O	O	O	
	Reduced flows lower quality of experience	O	O	O	
9. Fish and Wildlife:	Disruption of natural habitat due to impoundments and temperature changes	L	O	O	
	Salinity changes in estuary due to increased or decreased flows	O	O	O	
10. Solid Waste Disposal:	Increased seepage control	O	O	O	
	Competitive site use	O	O	O	
11. Liquid Waste Discharge:	Reduced flow augmentation if impoundments are used	L	O	O	
	Better treatment for withdrawal industry	O	O	O	
12. Flood Control:	Competitive storage use	O	O	O	
13. Drainage Control:		O	O	O	
14. Erosion Control:		O	O	O	

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3

NON-MONETARY BENEFITS AND COSTS

AREA 9
OBJECTIVE All
NEED 2-Industrial Process and Cooling

DEVICES	NEEDS	INTERACTIONS	BENEFITS EQ	BENEFITS NE	BENEFITS RD	EXC S-A	NEEDS	INTERACTIONS	COSTS EQ	COSTS NE	COSTS RD	EXC S-A
	15.Health:		O	O	O		15.Health		O	O	O	
	16.Visual and Cultural:						16.Visual and Cultural:					
		Creation of diversity through flatwater	O	O	O			Destruction of landscape by building of reservoirs	O	O	O	
		Wells do not disturb landscape	O	O	O			Water level fluctuation causes loss of shoreline access and natural beauty	O	O	O	
	17.Legal:						17.Legal:					
		Impoundments result in increase of local tax base	L	L	L			Impoundments result in loss of local tax base	O	O	O	

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4

NON-MONETARY BENEFITS AND COSTS

AREA 9
OBJECTIVE All
NEED 3-Rural Water Supply

DEVICES
- Wells
- Ponds
- Group Systems
- Extended Municipal Supplies
- Individual Supply
- Group Supply

NEEDS	INTERACTIONS	BENEFITS EQ	BENEFITS NE	BENEFITS RD	EXC S-A
1. Municipal and Industrial:	Allows larger more efficient regional systems	O	L	L	
	Disperse and multiply smaller systems	O	O	O	
2. Industrial Process and Cooling:	Complementary uses	O	O	O	
4. Irrigation:	Reuse of groundwater	O	O	O	
	Complementary use of surface water	O	O	O	
5. Power Cooling:	Complementary use	O	O	O	
6. Hydroelectric:	Complementary use	O	O	O	
7. Navigation:	Complementary use	O	O	O	
8. Recreation:	Provision of recreation sites	O	O	O	
9. Fish and Wildlife:	Creation of farm ponds for fishing	O	O	O	
	Increased waterfowl habitat	O	O	O	
10. Solid Waste Disposal:		O	O	O	
11. Liquid Waste Discharge:	Flow augmentation from groundwater sources	O	O	O	
12. Flood Control:	Provides some stream flow regulation	O	O	O	
	Increased infiltration due to lower groundwater level	O	O	O	
13. Drainage Control:	Withdrawal of groundwater lowers water table	O	O	O	

NEEDS	INTERACTIONS	COSTS EQ	COSTS NE	COSTS RD	EXC. S-A
1. Municipal and Industrial:	Competitive use with highly urbanized areas	O	O	O	
2. Industrial Process and Cooling:	Competitive use	O	O	O	
4. Irrigation:	Removal of harmful elements in return water	O	O	O	
5. Power Cooling:	Competitive use	O	O	O	
6. Hydroelectric:	Competitive use	O	O	O	
7. Navigation:	Reduced flows, blocked channels	O	O	O	
8. Recreation:	Loss of recreational sites	O	O	O	
9. Fish and Wildlife:	Impoundments destroy stream habitat	O	O	O	
	Possible deterioration or loss of habitat from lowered water table	O	O	O	
10. Solid Waste Disposal:	Increased location expenses for non-interference with source	O	O	O	
11. Liquid Waste Discharge:	Increased treatment and location expenses	O	O	O	
12. Flood Control:	Competitive storage use	O	O	O	
13. Drainage Control:		O	O	O	

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5

NON-MONETARY BENEFITS AND COSTS

AREA 9
OBJECTIVE All
NEED 3-Rural Water Supply

DEVICES	NEEDS	INTERACTIONS	BENEFITS EQ	BENEFITS NE	BENEFITS RD	EXC S-A
		14.Erosion Control:	O	O	O	
		15.Health:				
		Better quality of life by meeting sanitation and comfort requirements	O	O	O	
		Hand pumps, gasoline and diesel pumps and deep wells provide safe water after atomic fallout	O	O	O	
		Fire protection increased	O	O	O	
		16.Visual and Cultural:				
		Landscape diversity in ponds and wells	L	O	O	
		17.Legal:				
		Impoundments result in increase of tax base	O	O	O	

NEEDS	INTERACTIONS	COSTS EQ	COSTS NE	COSTS RD	EXC. S-A
	14.Erosion Control:	O	O	O	
	15.Health:				
	Dug wells are unsafe	O	O	O	
	Dug wells may fail in drought				
	Fire protection may be inadequate	O	O	O	
	16.Visual and Cultural:				
	Spread of urban growth into areas reserved for agriculture and open space	O	O	O	
	17.Legal:				
	Difficulties with municipalities over apportionment of water supply	O	O	O	

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6

AREA 9
OBJECTIVE All
NEED 4-Irrigation

NON-MONETARY BENEFITS AND COSTS

DEVICES	NEEDS	INTERACTIONS	BENEFITS EQ	BENEFITS NE	BENEFITS RD	EXC S-A
Sprinkler Gravity Flow Direct Diversion Wells Land Leveling	1. Municipal and Industrial:	Complementary use	O	O	O	
	2. Industrial Process and Cooling:		O	O	O	
	3. Rural Water Supply:		O	O	O	
	5. Power Cooling:		O	O	O	
	6. Hydroelectric:	Dual use	O	O	O	
	7. Navigation:	Flow increased by groundwater return	O	O	O	
	8. Recreation:	Complementary use	L	L	L	
	9. Fish and Wildlife:	Better food conditions for wildlife	M	M	M	
		Nutrient by-products for fish	O	O	O	
		Higher stream temperatures	O	O	O	
	10. Solid Waste Disposal:		O	O	O	
	11. Liquid Waste Discharge:		O	O	O	
	12. Flood Control:	Complementary use of storage	M	M	M	
	13. Drainage Control:	Withdrawal lowers water table	O	O	O	
	14. Erosion Control:	Increased soil cover and conservation	L	L	L	
	15. Health:	Sprinkled water is aerated providing simple form of treatment	O	O	O	

NEEDS	INTERACTIONS	COSTS EQ	COSTS NE	COSTS RD	EXC S-A
1. Municipal and Industrial:	Return flows require higher treatment levels; more nutrients and eutrophication	O	O	O	
	Competitive use during low flows	L	L	L	
2. Industrial Process and Cooling:	More treatment required	O	O	O	
	Competitive use	L	L	L	
3. Rural Water Supply:	Competitive use	L	L	L	
	Additional treatment	L	L	L	
5. Power Cooling:		O	O	O	
6. Hydroelectric:	Competitive use of water	O	O	O	
7. Navigation:	Reduced flows at critical periods	O	O	O	
8. Recreation:	Return water has high undesirable suspended solid concentration	L	L	L	
9. Fish and Wildlife:	Increase presence of toxic and fertilization elements in return water	L	L	L	
	Lessened stream flow during critical flow period	O	O	O	
	Higher stream temperatures	O	O	O	
	Encourages clean farming which decreases wildlife habitat	O	O	O	
10. Solid Waste Disposal:	Control of seepage and contamination of wells	O	O	O	
11. Liquid Waste Discharge:	Deterioration of water quality	L	L	L	
12. Flood Control:	Storage occupied at critical times	O	O	O	

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NON-MONETARY BENEFITS AND COSTS

AREA 9
OBJECTIVE A11
NEED 4-Irrigation

DEVICES	NEEDS	INTERACTIONS	BENEFITS EQ	BENEFITS NE	BENEFITS RD	EXC S-A
	16. Visual and Cultural:					
		Healthy plant species	[illegible]	[illegible]	M	
		Maintaining a uniform agricultural economy	[illegible]	[illegible]	L	
		Increased variety of landscape	[illegible]	[illegible]	[illegible]	
	17. Legal:		[illegible]	[illegible]	[illegible]	

NEEDS	INTERACTIONS	COSTS EQ	COSTS NE	COSTS RD	EXC S-A
13. Drainage Control:					
14. Erosion Control:					
	Increased cost by application of more water	[illegible]	[illegible]	[illegible]	
	Exposed fallow land	[illegible]	[illegible]	[illegible]	
15. Health:					
	Creates increased need for water control	[illegible]	[illegible]	[illegible]	
	Return water contains undesirable particulate and toxic matter	[illegible]	L	L	
16. Visual and Cultural:					
	Decreased variety of landscape				
17. Legal:		[illegible]	[illegible]	[illegible]	

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8

AREA 9
OBJECTIVE All
NEED 5-Power Cooling

NON-MONETARY BENEFITS AND COSTS

DEVICES: Wells, Diversions, Cooling Towers

NEEDS	INTERACTIONS	BENEFITS EQ	BENEFITS NE	BENEFITS RD	EXC S-A
1. Municipal and Industrial:	Complementary use	O	O	O	
2. Industrial Process and Cooling:	Complementary use	O	O	O	
3. Rural Water Supply:		O	O	O	
4. Irrigation:	High temperature water aids growth of some crops	L	O		
6. Hydroelectric:	Complementary use	O	O	O	
7. Navigation:	Complementary use	O	O	O	
8. Recreation:	More boating days if thermal pollution keeps streams from freezing	O	O	O	
9. Fish and Wildlife:	Possible improvement in crustacean and shellfish breeding in coastal areas	O	O	O	
	Increased use of area by resting waterfowl if kept from freezing	L	O	O	
10. Solid Waste Disposal:		O	O	O	
11. Liquid Waste Discharge:	Higher water temperature increases assimilative capacity of stream	L	O	O	
12. Flood Control:		O	O	O	
13. Drainage Control:	Withdrawal of groundwater lowers water table	O	O	O	
14. Erosion Control:		O	O	O	
15. Health:	Warm water decreases sedimentary capacity of streams	O	O	O	

NEEDS	INTERACTIONS	COSTS EQ	COSTS NE	COSTS RD	EXC. S-A
1. Municipal and Industrial:	Higher water temperature could cause taste and odor problem	O	O	O	
	Competitive use	O	O	O	
2. Industrial Process and Cooling:	Taste and Odor	O	O	O	
3. Rural Water Supply:	Competitive use of groundwater	O	O	O	
	Higher temperature of return water	O	O	O	
4. Irrigation:	Competitive use of water	O	O	O	
7. Navigation:	Competitive water use	O	O	O	
8. Recreation:	Competitive site use	M	O	O	
9. Fish and Wildlife:	Thermal pollution disrupts natural habitat	L	O	O	
	Harmful to marine organisms taken up into intakes	O	O	O	
	Reduction of aquatic life by mortality through condensers	L	O	O	
10. Solid Waste Disposal:		O	O	O	
11. Liquid Waste Discharge:	Water loss to stream	O	O	O	
	Lowered D.O. levels resulting in increased sulfides and acidity	O	O	O	
12. Flood Control:		O	O	O	
13. Drainage Control:		O	O	O	
14. Erosion Control:		O	O	O	
15. Health:	Fish kills	L	O	O	

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9

NON-MONETARY BENEFITS AND COSTS

AREA 9
OBJECTIVE All
NEED 5-Power Cooling

DEVICES	NEEDS	INTERACTIONS	BENEFITS EQ	BENEFITS NE	BENEFITS RD	EXC S-A	NEEDS	INTERACTIONS	COSTS EQ	COSTS NE	COSTS RD	EXC. S-A
	16. Visual and Cultural:	Landscape diversity	0	0	0		16. Visual and Cultural:	Cooling towers are unsightly	1	0	0	
								Greater aquatic growth in heated water	1	0	0	
								Fogs due to condensation of evaporated water	[illegible]	[illegible]	0	
	17. Legal:		0	0	0		17. Legal:		0	0	0	

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10

NON-MONETARY BENEFITS AND COSTS

AREA 9
OBJECTIVE All
NEED 6-Hydroelectric

DEVICES	NEEDS	INTERACTIONS	BENEFITS EQ	BENEFITS NE	BENEFITS RD	EXC S-A
Storage Run of River Diversion Pumped Storage Transmission Facilities	1. Municipal and Industrial:	Dual use of storage				
	2. Industrial Process and Cooling:	Maintains flow				
	3. Rural Water Supply:	Dual use of storage				
	4. Irrigation:	Dual use of storage				
	5. Power Cooling:	Maintains flow				
	7. Navigation:	Maintains flow				
	8. Recreation:	Provides fishing, boating, and water sports				
	9. Fish and Wildlife:	Increased fish habitat				
		Transmission right of ways increase edge effect which is beneficial to wildlife				
	10. Solid Waste Disposal:					
	11. Liquid Waste Discharge:	Maintains constant flow for discharge				
	12. Flood Control:	Site provides flood peak reduction				
	13. Drainage Control:					

NEEDS	INTERACTIONS	COSTS ED	COSTS NE	COSTS RD	EXC S-A
1. Municipal and Industrial:	Competitive use				
2. Industrial Process and Cooling:	Competitive use of water				
3. Rural Water Supply:	Competitive use of water				
4. Irrigation:	Competitive use of water				
5. Power Cooling:	Competitive use of water				
8. Navigation:	Competitive use of water				
8. Recreation:	Storage fluctuation reduces ease of access to water				
9. Fish and Wildlife:	Decreased wildlife habitat				
	Storage fluctuations disturb fish				
	Disruption of downstream flow levels				
	Obstruction to fish migration				
	Reduction of fish life through turbine mortality				
10. Solid Waste Disposal:					
11. Liquid Waste Discharge:					
12. Flood Control:	Competitive for storage				
13. Drainage Control:					

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NON-MONETARY BENEFITS AND COSTS

AREA 9
OBJECTIVE All
NEED 6-Hydroelectric

DEVICES	NEEDS	INTERACTIONS	BENEFITS EQ	BENEFITS NE	BENEFITS RD	EXC S-A
		14.Erosion Control: Regulates peak flow, reducing erosive capacity	0	0	0	
		15.Health:				
		16.Visual and Cultural: Provides water edge				
		17.Legal: Competition with private producers to keep down costs	3	3	3	

NEEDS	INTERACTIONS	COSTS EQ	COSTS NE	COSTS RD	EXC S-A
	14.Erosion Control:	0	0	0	
	15.Health:				
	16.Visual and Cultural: Water level fluctuations; Interruption of scenery by transmission lines				
	17.Legal:				

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12

AREA 9
OBJECTIVE All
NEED 7-Navigation

NON-MONETARY BENEFITS AND COSTS

DEVICES

- Permanent physical installation on waterways and banks
- Floating equipment
- Legal limitations on use of water
- Storage sites for water

BENEFITS

NEEDS / INTERACTIONS	EQ	NE	RD	EXC S-A
1. Municipal and Industrial:				
Increased real estate and beachfronts from landfill	O	O	O	
2. Industrial Process and Cooling:				
Complementary use of water	O	O	O	
3. Rural Water Supply:	O	O	O	
4. Irrigation:	O	O	O	
5. Power Cooling:				
Complementary use	O	O	O	
6. Hydroelectric:				
Complementary use	O	O	O	
8. Recreation:				
Increased surface area available for body contact sports	O	O	O	
Availability of alternatives for vacations	O	O	O	
Increase facilities for boating	L	O	O	
9. Fish and Wildlife:				
Greater access to commercial and sport fisheries	O	O	O	
10. Solid Waste Disposal:	O	O	O	
11. Liquid Waste Discharge:	O	O	O	
12. Flood Control:				
Increased channelization	O	O	O	
Shore protection	O	O	O	
Increased storage acreages	O	O	O	
13. Drainage Control:				
Stabilization and improvement of river banks	O	O	O	
14. Erosion Control:				
Stabilization of river banks	O	O	O	

COSTS

NEEDS / INTERACTIONS	EQ	NE	RD	EXC S-A
1. Municipal and Industrial:				
Decrease the water available	O	O	O	
Salt water intrusion	O	O	O	
Increase water treatment costs	O	O	O	
2. Industrial Process and Cooling:				
Conflict in availability of water	O	O	O	
3. Rural Water Supply:				
Increase surface water treatment costs	O	O	O	
4. Irrigation:				
Conflict in availability of water	O	O	O	
5. Power Cooling:				
Conflict in availability of water	O	O	O	
6. Hydroelectric:				
Conflict of water use	O	O	O	
8. Recreation:				
Pollution of body contact areas	O	O	O	
Filling in of recreation areas	L	O	O	
Taking down water levels for maintenance of canal water levels	O	O	O	
9. Fish and Wildlife:				
Competition for water on storage sites	O	O	O	
Decrease of water quality	L	O	O	
Dredging or filling of marshes or rivers	M	L	L	
Introduction of new species	O	O	O	
Loss of productive habitat	M	L	L	
10. Solid Waste Disposal:				
Competition for spoil sites	M	M	M	
11. Liquid Waste Discharge:				
Competition in use of waterway for carrying pollution	O	O	O	

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AREA 9
OBJECTIVE All
NEED 7-Navigation

NON-MONETARY BENEFITS AND COSTS

DEVICES	NEEDS	INTERACTIONS	BENEFITS EQ	BENEFITS NE	BENEFITS RD	EXC S-A
	15. Health:					
		Safety for boats and people	M	L	L	
		Increased mental health from waterfront activities	M	L	L	
	16. Visual and Cultural:					
		Increased visual effects from color and motion of harbors	M	L	L	
		Shipping and channel water edges	L	O	O	
		Shoreline development	O	O	O	
	17. Legal:					
		Competition with other means of transportation to decrease costs to consummers	O	O	O	

NEEDS	INTERACTIONS	COSTS EQ	COSTS NE	COSTS RD	EXC S-A
12. Flood Control:					
	Competition for storage sites	O	O	O	
	Decreased channelization	O	O	O	
	Decreased shore protection	O	O	O	
13. Drainage Control:		O	O	O	
14. Erosion Control:					
	Increase erosion of stream banks by boats and dredging	O	O	O	
15. Health:					
	Increased vector control costs	O	O	O	
	Decreased mental health from waterfront activities of a degraded nature	O	O	O	
16. Visual and Cultural:					
	Blighted waterfront, waterways	O	O	O	
17. Legal:					
	Control and coordination costs	O	O	O	

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14

AREA 9
OBJECTIVE All
NEED 8-Recreation

NON-MONETARY BENEFITS AND COSTS

DEVICES
Developing existing sites
Expansion and re-design included in other projects
New sites acquire access
Navigation improve-ment
Beach erosion control
Restoration of urban waterfront
Maintain quality and level of water

CONTINUED ON NEXT PAGE

Abbreviations

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NEEDS / INTERACTIONS	BENEFITS EQ	BENEFITS NE	BENEFITS RD	EXC S-A
1. Municipal and Industrial: Complementary use	L	L	L	
2. Industrial Process and Cooling: Complementary use	0	0	0	
3. Rural Water Supply: Complementary use	0	0	0	
4. Irrigation: Complementary use	0	0	0	
5. Power Cooling: Complementary use	0	0	0	
6. Hydroelectric: Complementary use	0	0	0	
7. Navigation: Complementary use Cape Cod Canal	L	0	L	
9. Fish and Wildlife: Multiple use of projects	H	M	H	
Creation of additional habitat	0	0	0	
10. Solid Waste Disposal:	0	0	0	
11. Liquid Waste Discharge:	0	0	0	
12. Flood Control: Complementary flood plain use	M	L	M	
13. Drainage Control:	0	0	0	
14. Erosion Control:	0	0	0	
15. Health: Increase in outdoor activities	H	M	M	

NEEDS / INTERACTIONS	COSTS EQ	COSTS NE	COSTS RD	EXC S-A
1. Municipal and Industrial: Competitive use	M	L	M	
2. Industrial Process and Cooling: Competitive use	L	0	L	
3. Rural Water Supply: Competitive use	0	0	0	
4. Irrigation: Competitive use	0	0	0	
5. Power Cooling: Competitive use	M	0	M	
6. Hydroelectric: Stop use for peak power	0	0	0	
Reduction of water level fluctuations	0	0	0	
7. Navigation: Cuts down on efficiency of use of large locks (recreational boating)	M	L	M	
Interference with large commercial vessels by small boats	M	L	M	
9. Fish and Wildlife: Less fishing and hunting in swimming and boating areas	H	M	H	
Deterioration or loss of habitat	0	L	L	
10. Solid Waste Disposal: Increased costs for covering spoil areas open to roadside and trailside view	L	0	0	
11. Liquid Waste Discharge: Better treatment for body contact activities	M	L	L	

NON-MONETARY BENEFITS AND COSTS

AREA 9
OBJECTIVE All
NEED 8-Recreation

DEVICES	NEEDS	INTERACTIONS	BENEFITS EQ	BENEFITS RE	BENEFITS RD	EXC S-A
Placement of storage sites	16. Visual and Cultural:	Tourist activities; sightseeing, cabin sites	M	L	H	
		Increased lakes, rivers, edges, and temperature moderation	M	L	M	
Storage facilities, size, type, extra equipment, limit of use	17. Legal:					

NEEDS	INTERACTIONS	COSTS			
12. Flood Control:	Reduced storage area due to allocation to recreation waters	L	O	L	
13. Drainage Control:		O	O	O	
14. Erosion Control:	Increased control for better views	O	O	O	
15. Health:	Increased quality of insect control for tourist comfort	M	L	L	
	Increased cost for same control because of use of less toxic means	M	L	L	
16. Visual and Cultural:	Increased skiing bothers some people	L	O	O	
	Site competition	L	O	O	
17. Legal:	Higher costs of control of boats, skiers, and swimmers	M	L	M	
	Higher control and allocation costs for water use	M	L	M	

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NON-MONETARY BENEFITS AND COSTS

AREA 9
OBJECTIVE All
NEED 9-Fish and Wildlife

DEVICES	NEEDS	INTERACTIONS	BENEFITS EQ	BENEFITS NE	BENEFITS RD	EXC S-A
Buying or legally retaining site access, preservation or maintenance of habitat	1. Municipal and Industrial:	Dual use of storage facilities	M	L	L	
	2. Industrial Process and Cooling:	Complementary use	0	0	0	
	3. Rural Water Supply:	Dual use of storage facilities	0	0	0	
Maintenance of water quality, level, and allocation	4. Irrigation:		0	0	0	
	5. Power Cooling:	Competitive use of water	0	0	0	
Placement of storage sites	6. Hydroelectric:	Increased power by having to take off water from high parts of the lake to obtain better oxygen levels in the river below	L	0	0	
Design of storage facilities, size, type, extra equipment	7. Navigation:					
	8. Recreation:	Added variety to outdoor recreational activities	H	M	H	
	10. Solid Waste Disposal:		0	0	0	
	11. Liquid Waste Discharge:	Complementary use of water	L	0	L	
	12. Flood Control:	Increased savings from more storage acreage (dams or protected flood plains)	H	M	H	
	13. Drainage Control:		0	0	0	
	14. Erosion Control:		M	L	M	

NEEDS	INTERACTIONS	COSTS EQ	COSTS NE	COSTS RD	EXC. S-A
1. Municipal and Industrial:	Loss of storage sites to protected streams or hunting areas	M	L	L	
	Loss of water used for retaining good waterfowl hunting and breeding areas	0	0	0	
2. Industrial Process and Cooling:	Competitive use	0	0	0	
3. Rural Water Supply:	Have to decrease the access of cattle to open water	L	0	0	
	Have to decrease the use of groundwater to maintain water table for marshes and streams	0	0	0	
4. Irrigation:	Increased damage to crops by small and big game	0	0	0	
	Increased cost of crop treatment - reduced use of toxic pesticides - to protect wildlife	L	0	L	
5. Power Cooling:	Complementary use of site	0	0	0	
6. Hydroelectric:	More equipment for protecting fish	M	L	M	
	Decreased power from a site due to having to take water from lower parts of the lake to have lower water temperature in the river below	0	0	0	
	Loss of power during peak times to decrease the rapidity and amount of water level variations	L	0	L	
7. Navigation:	Increased cost of spoil disposal of dredging operations	M	L	M	
8. Recreation:	Hunting annoys tourists and bird watchers	0	0	0	
	Fishing interferes with water skiing	L	0	L	
	New sport species affects native species	0	0	0	
	Commercial fishing interferes with sport fishing	L	0	L	

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NON-MONETARY BENEFITS AND COSTS

AREA 9
OBJECTIVE All
NEED 9-Fish and Wildlife

DEVICES	NEEDS	INTERACTIONS	BENEFITS EQ	BENEFITS NE	BENEFITS RD	EXC S-A
		15.Health:				
		Increase in outdoor activities: Mental health from boating and fishing	M	L	M	
		16.Visual and Cultural:				
		Increase of general tourism attracted to game	M	L	M	
		Increased lakes and edges	H	M	H	
		17.Legal:				

NEEDS	INTERACTIONS	COSTS EQ	COSTS NE	COSTS RD	EXC. S-A
	10. Solid Waste Disposal:				
	Not being able to use marshes for spoil sites	M	L	M	
	11.Liquid Waste Discharge:				
	Competitive use of water	H	M	H	
	12.Flood Control:				
	Decreased storage at a site during certain times of the year causes reduced protection or higher protection costs	L	O	L	
	13.Drainage Control:				
	Reduced to retain marshes and insure base flows to streams	L	O	L	
	14.Erosion Control:				
	More erosion protection for reduction of sedimentation	L	O	O	
	15.Health:				
	Increased cost of insect control	L	O	O	
	16.Visual and Cultural:				
	Use of wilderness for fishing and hunting	L	O	L	
	17.Legal:				
	Higher costs of agency coordination or creation of new agencies	M	L	M	
	Higher hunter and fisherman control costs	L	O	L	

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NON-MONETARY BENEFITS AND COSTS

AREA 9
OBJECTIVE ALL
NEED 10-Solid Waste Disposal

DEVICES
Dump
Sanitary land fill
Incinerators
Sea Disposal
Re-processing and re-use

NEEDS / INTERACTIONS	BENEFITS EQ	BENEFITS RE	BENEFITS PD	EXC S-A
1. Municipal and Industrial: Waste heat of waste incineration used for brackish and seawater distillation	O	O	O	
2. Industrial Process and Cooling:	O	O	O	
3. Rural Water Supply:	O	O	O	
4. Irrigation:	O	O	O	
5. Power Cooling:	O	O	O	
6. Hydroelectric:	O	O	O	
7. Navigation:	O	O	O	
8. Recreation:	O	O	O	
9. Fish and Wildlife:	O	O	O	
11. Liquid Waste Discharge:	O	O	O	
12. Flood Control:	O	O	O	
13. Drainage Control: Dump material	O	O	O	
14. Erosion Control: Filling of gullys and lining of stream banks by reprocessed or compacted solid waste	L	O	O	
15. Health:				
Reduction of communicable diseases	M	L	L	
Vector control	O	O	O	
Improvement in water quality	O	O	O	
16. Visual and Cultural: More attractive landscape qualities inducing increase in tourism, business and habitation	L	O	O	
17. Legal:				

NEEDS / INTERACTIONS	COSTS EQ	COSTS RE	COSTS PD	EXC S-A
1. Municipal and Industrial: Contamination of supply by seepage	O	O	O	
2. Industrial Process and Cooling:	O	O	O	
3. Rural Water Supply: Contamination of supply by seepage	O	O	O	
4. Irrigation:	O	O	O	
5. Power Cooling:	O	O	O	
6. Hydroelectric:	O	O	O	
7. Navigation:	O	O	O	
8. Recreation: Unsightly dumping grounds within recreational domains	O	O	O	
9. Fish and Wildlife: Destruction of habitat particularly swamp and marshland	L	O	O	
11. Liquid Waste Discharge:	O	O	O	
12. Flood Control:	O	O	O	
13. Drainage Control: Negative changes in topography	O	O	O	
14. Erosion Control:				
15. Health:				
Incineration creates air pollution	O	O	O	
Dumping creates vector control problems	O	O	O	
16. Visual and Cultural:				
Proximity of housing to a dump: decreased land value	O	O	O	
Odor and esthetic degradation	O	O	O	
17. Legal:				

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NON-MONETARY BENEFITS AND COSTS

AREA 9
OBJECTIVE All
NEED 11-Liquid Waste Discharge

DEVICES

Injection wells
Dilution Treatment
Spray disposal of treated effluent

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NEEDS / INTERACTIONS	BENEFITS EQ	BENEFITS NE	BENEFITS RD	EXC S-A
1. Municipal and Industrial:				
Improved quality of water when treated	L	L	L	
Increase groundwater recharge	O	O	O	
2. Industrial Process and Cooling:				
Reuse of effluent	O	O	O	
3. Rural Water Supply:				
Complementary use of water	O	O	O	
4. Irrigation:				
Increase groundwater recharge	O	O	O	
Added nutrients	O	O	O	
5. Power Cooling:				
Complementary uses of sites	O	O	O	
6. Hydroelectric:				
Complementary uses of sites	O	O	O	
7. Navigation:				
Complementary uses of sites	O	O	O	
8. Recreation: Quality	H	H	H	
9. Fish and Wildlife:				
Improvement of habitat-nutrition	H	H	H	
10. Solid Waste Disposal:	O	O	O	
12. Flood Control:	O	O	O	
13. Drainage Control:	O	O	O	
14. Erosion Control:	O	O	O	
15. Health:				
Insect control	L	L	L	
Nutrient control	O	O	O	
Lessened disease transmission when treated	M	M	M	
16. Visual and Cultural:	M	L	M	
17. Legal:	O	O	O	

NEEDS / INTERACTIONS	COSTS EQ	COSTS NE	COSTS RD	EXC. S-A
1. Municipal and Industrial:				
Increased costs for advanced treatment	H	H	H	
2. Industrial Process and Cooling:				
Increased treatment	H	H	H	
3. Rural Water Supply:				
Additional treatment required	O	O	O	
4. Irrigation:				
Toxic or acidic minerals or compounds may require treatment	O	O	O	
5. Power Cooling:	O	O	O	
6. Hydroelectric:				
Faster erosion of equipment	O	O	O	
7. Navigation:				
Maintenance of corrodable installations and vessels	O	O	O	
8. Recreation:				
Increased treatment costs	O	O	O	
Decreased value due to pollution, odor, color	O	O	O	
Eutrophication may cause unwanted floral and faunal blooms	O	O	O	
9. Fish and Wildlife:				
Overfertilization	O	O	O	
Depletion of oxygen	O	O	O	
Chlorination has adverse effects on aquatic life	O	O	O	
Too much pollution dilution, water released upstream to compensate for low flow downstream reduces upstream water fish ability	O	O	O	
10. Solid Waste Disposal:	O	O	O	
12. Flood Control:	O	O	O	
13. Drainage Control:	O	O	O	
14. Erosion Control:	O	O	O	

NON-MONETARY BENEFITS AND COSTS

AREA 9
OBJECTIVE All
NEED 11-Liquid Waste Discharge

DEVICES	NEEDS	INTERACTIONS	BENEFITS EQ	BENEFITS NE	BENEFITS RD	EXC S-A

NEEDS	INTERACTIONS	COSTS EQ	COSTS NE	COSTS RD	EXC. S-A
15.Health:					
	Groundwater contamination	0	0	0	
	Untreated waste causes vector control costs	0	0	0	
16.Visual and Cultural:					
	Oxidation of untreated wastes results in mass mortality of marine organism	0	0	0	
17.Legal:		H	H	H	

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AREA 9
OBJECTIVE ALL
NEED 12-Flood Control

NON-MONETARY BENEFITS AND COSTS

DEVICES
Physical controls in channel
Storage
Groundwater recharge
Emergency measures
Structural protection
Diversions
Legal controls: Zoning of flood plain use, Flood plain insurance, Limited use

NEEDS	INTERACTIONS	BENEFITS LO	BENEFITS NE	BENEFITS RD	EXC S-A
1. Municipal and Industrial:	Prevention of disruption of water supply	O	O	O	
	Augmentation of water supply	L	L	L	
2. Industrial Process and Cooling:	Complementary use of storage	O	O	O	
3. Rural Water Supply:	Complementary use	O	O	O	
4. Irrigation:	Prevention of crop losses	O	O	O	
	Complementary uses	O	O	O	
5. Power Cooling:	Complementary uses	O	O	O	
6. Hydroelectric:	Augmentation of power water supply	O	O	O	
7. Navigation:	Regulation or augmentation of water	O	O	O	
8. Recreation:	Expansion of available facilities and water	H	M	M	
	Zoned flood plains for recreation	H	M	M	
	Maintain levels of lakes and ponds on flood plains	M	L	L	
9. Fish and Wildlife:	Increased water area through impoundment construction	L	O	O	
	Decreased damage to fish from storm waters	O	O	O	
10. Solid Waste Disposal:		O	O	O	
11. Liquid Waste Discharge:	Complementary uses	O	O	O	
13. Drainage Control:		O	O	O	

NEEDS	INTERACTIONS	COSTS LO	COSTS NE	COSTS RD	EXC S-A
1. Municipal and Industrial:	Competition for storage	O	O	O	
2. Industrial Process and Cooling:	Competitive uses	O	O	O	
3. Rural Water Supply:	Limitations on available groundwater supply	O	O	O	
4. Irrigation:	Competitive uses	O	O	O	
5. Power Cooling:	Competitive uses	O	O	O	
6. Hydroelectric:	Reduction of available water for power	O	O	O	
7. Navigation:	Reduction of available water for water levels				
8. Recreation:	Reduction of available water or water levels	O	O	O	
	Reduce access to waterfront due to fluctuation	L	O	O	
9. Fish and Wildlife:	Reduction of water available for maintaining levels	O	O	O	
	Impoundments may destroy habitat	O	O	O	
	Possibility of changed estuarine environment	O	O	O	
10. Soild Waste Disposal:		O	O	O	
11. Liquid Waste Discharge:	Reduction of stored water to maintain minimum levels	O	O	O	
	Increased pumping and other costs to dispose of liquid wastes during floods	O	O	O	
13. Drainage Control:	Decreased drainage for storage	O	O	O	

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NON-MONETARY BENEFITS AND COSTS

AREA 9
OBJECTIVE ALL
NEED 12-Flood Control

DEVICES	NEEDS	INTERACTIONS	BENEFITS EQ	BENEFITS NE	BENEFITS RD	EXC S-A
	14. Erosion Control:					
		Prevents large losses due to floods	H	L	L	
	15. Health:					
		Reduction in loss of life	L	L	L	
		Evacuation, relief, and rehabilitation of victims	0	0	0	
		Control of diseases due to backing up of storm and sanitary sewers	L	0	0	
		Improvement in mental well being	L	0	0	
	16. Visual and Cultural:					
		Less chance of destruction of habitat	M	L	L	
		Increase in variability of environment by creation of impoundments	L	0	0	
	17. Legal:		0	0	0	

NEEDS	INTERACTIONS	COSTS EQ	COSTS NE	COSTS RD	EXC S-A
14. Erosion Control:					
	May increase erosion by reduction of sediments required to maintain stream beds and banks and shores of coastal areas	0	0	0	
15. Health::		0	0	0	
16. Visual and Cultural:					
	Reduction in waterfront enjoyment	0	0	0	
17. Legal:					
	Cost of insurance and zoning control	L	M	H	
	Cost of reservoir storage space coordination	0	0	0	

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NON-MONETARY BENEFITS AND COSTS

AREA 9
OBJECTIVE NEC
NEED 13-Drainage Control

DEVICES	NEEDS	INTERACTIONS	BENEFITS LO	BENEFITS HE	BENEFITS RD	EXC S-A
Remove water or prevent water entrance by: Wells Channels Fill Diversions	1.	Municipal and Industrial: Increased water supply	O	O	O	
	2.	Industrial Process and Cooling: Possible source of water	O	O	O	
	3.	Rural Water Supply: Increased water supply	O	O	O	
	4.	Irrigation: Easier application	L	L	L	
		Source of water	O	O	O	
	5.	Power Cooling:	O	O	O	
	6.	Hydroelectric:	O	O	O	
	7.	Navigation:	O	O	O	
	8.	Recreation: Higher quality natural recreational area	M	L	L	
	9.	Fish and Wildlife: Drainage of forest land results in greater yield of wildlife	H	H	H	
	10.	Solid Waste Disposal: Lessened contamination of groundwater	O	O	O	
	11.	Liquid Waste Discharge:	O	O	O	
	12.	Flood Control: Augments flood control methods	O	L	L	
	14.	Erosion Control: Augments erosion control methods	O	O	O	
	15.	Health: Decreased vector control	H	M	M	

NEEDS	INTERACTIONS	COSTS LO	COSTS HE	COSTS RD	EXC S-A
1.	Municipal and Industrial: Decreased shallow aquifer recharge	O	O	O	
	Lower groundwater table	O	O	O	
2.	Industrial Process and Cooling:	O	O	O	
3.	Rural Water Supply: Decreased shallow aquifer recharge	O	O	O	
4.	Irrigation:	O	O	O	
5.	Power Cooling:	O	O	O	
6.	Hydroelectric:	O	O	O	
7.	Navigation: Decreased base flow	O	O	O	
8.	Recreation:	O	O	O	
9.	Fish and Wildlife: Destruction of swamp and marshland habitat	M	O	O	
	Lessened base flow of streams	O	O	O	
	Alteration of estuarine environment	O	O	O	
	Less waterfowl habitat	M	O	O	
	Less edge game cover in drained cropland	M	O	O	
10.	Solid Waste Disposal:	O	O	O	
11.	Liquid Waste Discharge: Lessened base flows concentrate waste during low flow creating higher costs	O	O	O	
12.	Flood Control: Increases runoff	O	O	O	
14.	Erosion Control: Increased erosion	O	O	O	
15.	Health: Decreased mental health due to less variety of experience	O	O	O	

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AREA 9
OBJECTIVE ALL
NEED 13-Drainage Control

NON-MONETARY BENEFITS AND COSTS

DEVICES	NEEDS	INTERACTIONS	BENEFITS EQ	BENEFITS NE	BENEFITS RD	EXC S-A
	16. Visual and Cultural:					
		Improved quality of natural forest, marsh and swamp land	0	0	0	
	17. Legal:		0	0	0	

NEEDS	INTERACTIONS	COSTS EQ	COSTS NE	COSTS RD	EXC S-A
16. Visual and Cultural:					
	Decreased diversity	0	0	0	
	Land subsidence	0	0	0	
	Possible tidal flooding in marginal land areas	0	0	0	
	Decreased quality of natural forest, marsh and swamp land	M	L	L	
17. Legal:		0	0	0	

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NON-MONETARY BENEFITS AND COSTS

AREA 9
OBJECTIVE ALL
NEED 14-Erosion

DEVICES

Flow diversion
Soil cover
Soil use
Mulches
Soil binders
Paving
Channels
Dams

BENEFITS

NEEDS / INTERACTIONS	EQ	NE	RD	EXC S-A
1. Municipal and Industrial: Decrease treatment cost for silt removal	L	L	L	
2. Industrial Process and Cooling: Decreased silt removal	0	0	0	
3. Rural Water Supply: Decreased silt removal	0	0	0	
4. Irrigation: Greater crop yields	0	0	0	
5. Power Cooling: Reduces suspended material in water	0	0	0	
6. Hydroelectric:	0	0	0	
7. Navigation: Decreases channel maintenance	M	L	M	
8. Recreation: Increased desirability of water sports	L	0	0	
Creation of sites for water sports	0	0	0	
9. Fish and Wildlife: Increased habitat desirability	H	M	H	
Increased light penetration in water aids plant growth providing food and cover	L	0	0	
10. Solid Waste Disposal: Dual site use	0	0	0	
11. Liquid Waste Discharge: Sediment load in stream reduced	M	L	L	
Sediment from newly developed areas does not clog storm sewers	0	0	0	

COSTS

NEEDS / INTERACTIONS	EQ	NE	RD	EXC S-A
1. Municipal and Industrial:	0	0	0	
2. Industrial Process and Cooling:	0	0	0	
3. Rural Water Supply:	0	0	0	
4. Irrigation:	0	0	0	
5. Power Cooling:	0	0	0	
6. Hydroelectric:	0	0	0	
7. Navigation:	0	0	0	
8. Recreation: Loss of water edge sites for camping due to bank protection	0	0	0	
9. Fish and Wildlife: Devices affect ecology	0	0	0	
10. Solid Waste Disposal:	0	0	0	
11. Liquid Waste Discharge:	0	0	0	
12. Flood Control:	0	0	0	
13. Drainage Control:	0	0	0	
15. Health: Increases vectors due to water retardation	L	0	0	
16. Visual and Cultural: Control reduces variety of landscapes	0	0	0	
Reduces provision of raw material for natural shore and beach renewal	0	0	0	
17. Legal:	0	0	0	

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AREA 9

OBJECTIVE ALL

NEED 14-Erosion Control

NON-MONETARY BENEFITS AND COSTS

DEVICES	NEEDS	INTERACTIONS	BENEFITS EQ	BENEFITS NE	BENEFITS RD	EXC S-A	NEEDS	INTERACTIONS	COSTS EQ	COSTS NE	COSTS RD	EXC S-A
	12. Flood Control:											
		Increases reservoir storage life	L	L	L							
		Augments flood control methods	L	L	L							
		Dual site use										
	13. Drainage Control:											
		Sediment does not clog system	L	L	L							
		Provides stable outlets	O	O	O							
	15. Health:		O	O	O							
	16. Visual and Cultural:											
		Increases beauty	M	L	L							
	17. Legal:		O	O	O							

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AREA 9
OBJECTIVE ALL
NEED 15-Health

NON-MONETARY BENEFITS AND COSTS

DEVICES	NEEDS	INTERACTIONS	BENEFITS EQ	BENEFITS NE	BENEFITS RD	EXC S-A
Insect control Limiting use of pesticides Control of beach and bathing diseases Elimination of septic tanks Reduction of air pollution by greater use of nuclear power or hydro-power Treatment of water supplies beyond minimum health standards	1.	Municipal and Industrial: Complementary uses of treatment benefits	0	0	0	
	2.	Industrial Process and Cooling:	0	0	0	
	3.	Rural Water Supply: Complementary uses of treatment benefits	0	0	0	
	4.	Irrigation:	0	0	0	
	5.	Power Cooling:	0	0	0	
	6.	Hydroelectric:	0	0	0	
	7.	Navigation:	0	0	0	
	8.	Recreation: Complementary uses of treated water	H	H	H	
	9.	Fish and Wildlife:	0	0	0	
	10.	Solid Waste Disposal:	0	0	0	
	11.	Liquid Waste Discharge:	0	0	0	
	12.	Flood Control:	0	0	0	
	13.	Drainage Control:	0	0	0	
	14.	Erosion Control:	0	0	0	
	16.	Visual and Cultural: Reduced visual pollution in waters	0	0	0	
	17.	Legal:	0	0	0	

NEEDS	INTERACTIONS	COSTS EQ	COSTS NE	COSTS RD
1.	Municipal and Industrial: Increased treatment of water, including its taste, softening, fluoride and odor	0	0	0
2.	Industrial Process and Cooling:	0	0	0
3.	Rural Water Supply: Better treatment for human consumption	0	0	0
4.	Irrigation:	0	0	0
5.	Power Cooling: Decrease the use or increase the effectiveness of cooling towers to decrease accidents from fog	0	0	0
6.	Hydroelectric:	0	0	0
7.	Navigation:	0	0	0
8.	Recreation: Increase supply of water oriented recreation facilities above the point of immediate or local positive benefits to help deprived or poverty areas or low recreation areas of all types	H	H	H
	Increased costs of eliminating water carried diseases	H	H	H
9.	Fish and Wildlife: Many pesticides detrimental to fish and wildlife	L	L	L
	Mosquito drainage damages valuable marshlands	0	0	0
10.	Solid Waste Disposal: Increase costs of taking care of spoil to point where it has no smell or affects upon health	0	0	0
11.	Liquid Waste Discharge: Increased treatment costs	0	0	0
	Increase costs of taking care of affluents to point where it has no smells or affects upon health	0	0	0
12.	Flood Control:	0	0	0

Abbreviations

EXC. S-A = Except Sub-Areas
H = high
M = medium
L = low
0 = zero or insig.

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AREA 9
OBJECTIVE ALL
NEED 15-Health

NON-MONETARY BENEFITS AND COSTS

DEVICES	NEEDS	INTERACTIONS	BENEFITS EQ	BENEFITS NE	BENEFITS RD	EXC S-A

NEEDS	INTERACTIONS	COSTS EQ	COSTS NE	COSTS RD	EXC. S-A
	13.Drainage Control:	0	0	0	
	14.Erosion Control:	0	0	0	
	16.Visual and Cultural:	0	0	0	
	17.Legal: High cost of acquiring and enforcing control	0	0	0	

Abbreviations

EXC. S-A = Except Sub-Areas
H = high
M = medium
L = low
0 = zero or insig.

NON-MONETARY BENEFITS AND COSTS

AREA 9
OBJECTIVE All
NEED 16-Visual and Cultural

DEVICES
Legal
Site preservation
Design of sites
Design of device

NEEDS	INTERACTIONS	BENEFITS EQ	BENEFITS PE	BENEFITS RD	EXC S-A
1. Municipal and Industrial:		0	0	0	
2. Industrial Process and Cooling:		0	0	0	
3. Rural Water Supply:		0	0	0	
4. Irrigation:		0	0	0	
5. Power Cooling:		0	0	0	
6. Hydroelectric:		0	0	0	
7. Navigation:		0	0	0	
8. Recreation:	Pleasing environment results in greater recreational participation	H	M	H	
9. Fish and Wildlife:	May aid productivity of wildlife	H	M	H	
10. Solid Waste Disposal:		0	0	0	
11. Liquid Waste Discharge:		0	0	0	
12. Flood Control:		M	L	M	
13. Drainage Control:		L	0	L	
14. Erosion Control:	Many of visual and cultural devices serve as erosion control devices				
15. Health:	Esthetics and physical and mental health are often complementary	H	M	H	
17. Legal:		0	0	0	

NEEDS	INTERACTIONS	COSTS EQ	COSTS PE	COSTS RD	EXC. S-A
1. Municipal and Industrial:	Increased cost of devices (all devices)	L	0	L	
2. Industrial Process and Cooling:	Increased cost in design and installation of esthetic devices	L	0	L	
3. Rural Water Supply:	Increased cost in design of pumping stations	0	0	0	
4. Irrigation:		0	0	0	
5. Power Cooling:	Design of environmentally integrated installations	H	L	M	
6. Hydroelectric:	Design of environmentally integrated installations	0	0	0	
7. Navigation:	Device cost increased to allow a more pleasurable type canal to be built	L	0	L	
8. Recreation:	Some measures restrict recreation in certain areas: skiing, boating	L	0	L	
9. Fish and Wildlife:	May hurt present fish and wildlife species	0	0	0	
10. Solid Waste Disposal:	Increased cost for covering spoil areas open to any view	L	0	L	
11. Liquid Waste Discharge:	Better treatment for visual pleasure	H	M	H	
12. Flood Control:	Increased cost due to the need of decreased fluctuation for visual appearance	L	0	L	
	Optimum water edge design	M	L	M	

Abbreviations

EXC. S-A = Except Sub-Areas
H = high
M = medium
L = low
0 = zero or insig.

NON-MONETARY BENEFITS AND COSTS

AREA 9
OBJECTIVE All
NEED 16-Visual and Cultural

DEVICES	NEEDS	INTERACTIONS	BENEFITS EQ	BENEFITS NE	BENEFITS RD	EXC S-A	NEEDS	INTERACTIONS	COSTS SE	COSTS NE	COSTS RD	EXC S-A
								13. Drainage Control: Increased costs in esthetic implementation of devices	L	O	L	
								14. Erosion Control: Increased cost in implementation of devices	O	O	O	
								15. Health:	O	O	O	
								17. Legal: High cost of acquiring control of design situations	M	L	M	

Abbreviations

EXC. S-A = Except Sub-Areas
H = high
M = medium
L = low
O = zero or insig.

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DEVICE INTERACTIONS

The device interaction sheets show estimated degrees of beneficial and adverse effects on the fulfillment of various needs when specified devices are used to satisfy a particular need. These tables are not final output to go with the recommendations of the study, but rather were utilized as references in discussions of work group and other meetings when consideration was given to combinations of methods and devices to be used in satisfying demands in the NAR areas.

There is a table for each of the 17 NAR needs for each area, for each objective. Each table includes estimates ranging from zero through low, medium and high for the positive and negative effects on other needs of the are when a particular device is used to fulfill the need for which the table has been prepared. Although the estimation of exact numerical effects of this type, monetary and non-monetary, would have required resources far beyond those available for the study, the broad estimates provided here appeared to be relatively easy to make, given the wide experience with water resources planning that has been accumulated. The estimates shown were reviewed by experienced persons associated with the study before bein presented in tables for each area.

Device interaction judgement were not made for each of the benchmark years. This facilitated discussion in terms of generally similar sets of interactions over the planning period without ruling out important comment on and consideration of specified changes in technology.

CHAPTER 5

THIRD STAGE OF PLAN FORMULATION

DEPARTMENT OF THE ARMY
NORTH ATLANTIC DIVISION, CORPS OF ENGINEERS
90 CHURCH STREET
NEW YORK, N. Y. 10007

IN REPLY REFER TO

6 October 1970

PLAN FORMULATION MEMORANDUM 17
TO MEMBERS OF THE AD HOC WORK GROUP ON PLAN FORMULATION
NORTH ATLANTIC REGIONAL WATER RESOURCES STUDY

The date and location of the series of meetings for the third phase of plan formulation is given below. It is planned that these meetings will start at 9:00 a.m. each day and end in the early afternoon of the second day. Please bring all material you will need for mixed-objective plan formulation including second round data, appendix drafts, etc.

Plan Formulation Meetings

20-21 Oct.	-	Subregion A; Augusta, Maine Room 114, State Office Building State and Capitol Sts.
26-27 Oct.	-	Subregion F; Richmond, Virginia Room 7314, Federal Building, 400 N. 8th St.
12-13 Nov.	-	Subregion B; Boston, Mass. Room 2308, JFK Federal Building
17-18 Nov.	-	Subregion C; Albany, New York Room 108B, Conservation Building (New), 50 Wolf Road
24-25 Nov.	-	Subregion D; Harrisburg, Pa. Room 309, Agricultural Building, 2301 N. Cameron St.
1-2 Dec.	-	Subregion E; Baltimore, Md. Room 108, Federal Office Building, 31 Hopkins Plaza

Timing for the plan formulation meetings is extremely critical, so please make your arrangements to attend as soon as possible. Members should make their own hotel reservations.

In accordance with the decision of the Coordinating Committee at Lake Luzerne, a round of preparatory meetings with each state and river basin commission was scheduled before the start of plan formulation. These

meetings are now underway and the schedule is given below for your information.

State Meetings

5 Oct.	-	New England River Basins Commission, Boston
6 Oct.	-	Virginia, Richmond; Pennsylvania, Harrisburg
7 Oct.	-	Delaware, Dover; Delaware River Basin Commission, Dover
8 Oct.	-	New Hampshire, Concord; West Virginia, Charleston
9 Oct.	-	New York, Albany
12 Oct.	-	Maine, Augusta
13 Oct.	-	Rhode Island, Providence; Maryland, Riverdale; District of Columbia, Riverdale
14 Oct.	-	Vermont, Montpelier
15 Oct.	-	Massachusetts, Boston
16 Oct.	-	Connecticut, Hartford

HARRY E. SCHWARZ
Chairman
Plan Formulation Work Group

DEPARTMENT OF THE ARMY
NORTH ATLANTIC DIVISION, CORPS OF ENGINEERS
90 CHURCH STREET
NEW YORK, N. Y. 10007

IN REPLY REFER TO

23 December 1970

MEMORANDUM 71-13
TO MEMBERS OF THE COORDINATING COMMITTEE
NORTH ATLANTIC REGIONAL WATER RESOURCES STUDY

Inclosed is a draft plan formulation report on one of the NAR Study areas (Basin 21 - James River Basin). Each area will be prepared in a similar manner and inserted as a section in the final report of the study. Please familiarize yourself with the report so that it can be discussed at the Coordinating Committee meeting on 6 and 7 January in Providence, Rhode Island.

The inclosed report is intended to be short, concise, and straightforward, yet comprehensive enough to give the reader the information he needs to understand the water and related resource problems and possible solutions for the area. While it is felt that the description of the needs and the program for the mixed objective is a valid representation of the results of plan formulation, it should be noted that there will be changes as well as additions to the numerical data. These data have been supplied in several cases only to give an idea of the range the final figures may have.

A copy of the tentative agenda for the Coordinating Committee meeting in Providence is also inclosed.

E. T. Fleming, Jr.
for HARRY E. SCHWARZ
Executive Secretary

2 Incls.
a/s

DRAFT REPORT ON PLAN FORMULATION

AREA 21

James River Basin. Area 21 is located primarily in the State of Virginia, with a small western section of it in West Virginia. This area is presently one of the less developed portions of the North Atlantic Region. About 20 per cent of it is in Appalachia. Per capita income was 11.4 per cent below the national average in 1959, but is projected to increase to only 5 per cent below the national average by 2020. The NAR Study is being coordinated with the Type II survey study underway in the basin.

Mixed Objective. Water resources planning in the James River Basin should emphasize Regional Development. This emphasis should include some leaning towards Environmental Quality, except in the large cities where the focus should be aimed at National Efficiency.

Needs to be Satisfied. Water and land related needs in the James River Basin, reflections of the area's mixed objective, are shown in Table 1. This will be an area of rapid growth for the next fifty years and its water withdrawal needs will be extremely large for industry and power cooling. Instream needs for liquid waste disposal will be very high, as will the land related needs for erosion control.

There are other needs that are important to the area's growth. The effects of water pollution and of spoil disposal from dredging upon the area's sea oyster farms must be determined. Visual quality needs require additional open spaces and water surfaces in the landscape of this basin. More access to the waterfronts of the basin is needed for additional recreation and visual benefits.

To assure good choices between alternative objectives and means for resource development, needs for public information and education and interchange of data and ideas among local, state and Federal interests will be high.

Growth rates of needs are very important as they must be reflected later by the proper timing of devices. Most of the area's needs have a steady and high growth rate because of the basin's expected increased rate of development. There are other needs, however, that have a slow or zero growth rate and these include: agricultural irrigation, cropland drainage, and agricultural and shoreline erosion needs. Urban erosion needs will experience an exceptionally large increase during the latter part of the study period.

Devices. The devices presently considered for Area 21 are shown in Table 2 along with the needs each device will serve. Many water needs are shown to be dependent upon different types of reservoir storage in the James River Basin. These include municipal and industrial water, irrigation, hydroelectric power generation, liquid waste disposal and flood control. Some needs, such as municipal and industrial water, rural domestic and livestock

water and irrigation will also be dependent upon wells. Power cooling withdrawals during the period of study will shift from fresh to brackish and then to saline water sources.

Rural self-supplied water facilities will decrease because of an increasing shift to central water systems. Changes in navigation will be limited by the 55-foot draft allowed by the Chesapeake Bay bridge-tunnel and the Norfolk harbor tunnel, but a 32-foot channel to Richmond will be built. The pollution control devices that are checked will be stressed to comply with state and Federal water quality standards in addition to aiding the oyster farming industry. Maximum reliance will be placed upon reservoirs and local flood protection measures to satisfy flood control needs in the basin due, partly, to a lack of local interest in flood plain management.

Programs should be developed to inform the basin's population of their water resource planning problems and possible solutions including the siting of reservoirs, power plants, etc. Visual and cultural landscape (land and access) needs can be met by the early use of purchasing.

Benefits. The devices indicated considered in the NAR program would satisfy all of the area's needs. Those needs shown in Table 1 are, therefore, system output benefits of this area's program.

Additional benefits arise from multiple-use of the devices in the program. The largest multiple-uses involves reservoirs that can serve municipal and industrial water needs in addition to recreation, fish and wildlife, irrigation, flood control and hydroelectric needs. Meeting water quality needs will greatly aid the area's visual and cultural and oyster farming needs. Meeting the visual and cultural needs could enhance recreational opportunities. Improvements in mainstem channels for commercial navigation will also meet some needs for recreational boating. Cooling towers for power plants will reduce withdrawal requirements as well as thermal pollution.

Costs. Monetary costs for the program are shown in Table 3. Generally, the levels and the timing of these costs follow the levels and timing of the needs shown in Table I. Costs for flood control needs are high during the early years of the program. Additional costs for power cooling facilities to meet the mixed objective become very high in the later years. Erosion costs are high and may turn out to be higher because of the lack of existing erosion programs in urban areas.

Liquid waste control costs are extremely high. These are rough figures due to the lack of definitive information on particular devices and possible implementation programs.

Satisfying a particular need through the use of certain devices can have costly effects on the satisfaction of other needs. For example, dredging for navigation may interfere with oyster farming in the basin or pumped storage for hydroelectric needs may interfere with fish migrations, recreation and visual and cultural needs.

Alternatives. Environmental Quality can be emphasized in the James River Basin primarily by discouraging the expected rapid growth in the area. This change would reduce the high level of needs and costs in the area especially for liquid waste disposal, municipal and industrial water, power cooling and urban erosion. The visual and cultural environment and recreational fish and wildlife activities would be enhanced.

National Efficiency can be emphasized by allowing more of the power cooling water withdrawal needs to be met in the estuaries, and by using less flood plain management practices for flood control. Costs would be reduced for both needs as a result of these actions. The municipal and industrial water needs, as well as the liquid waste disposal needs, would be lower under the National Efficiency objective with resulting decreases in cost.

TABLE - 1 /7
NEEDS

		Present	1980	2000	2020
Municipal & Industrial	(mgd)	185	253	400	662
Industrial Process & Cooling - fresh	(mgd)	419	901	2076	4770
Rural Water Supply	(mgd)	19	29	48	56
Irrigation: agriculture	(1000 afy)	2.4	23.8	61.4	72.9
non-agriculture	(1000 afy)	2.4	10.6	18.6	29.0
Power Cooling: withdrawal - saline	(cfs)	800	700	3800	5000
brackish	(cfs)	0	5300	5300	3000
fresh	(cfs)	1850	1700	4680	7300
consumption - brackish	(cfs)	0	49	49	30
fresh	(cfs)	19	17	90	153
Hydroelectric	(mw)	50	1000	2500	2500
Navigation: commercial (million tons annually)		62	79	121	198
recreation (boats - 1000's/% berthed)		44/3	59/3	78/3	125/3
Water Recreation: visitor days (million)			8	12	15
/2 stream or river miles			0	0	0
surface acres (1,000) /3			20	15	10
beach (acres)/pool (square feet)			0/0	1/2	1/2.5
land facilities (1,000 acres)			5	3	4
Fish & Wildlife: fishing - man-days (millions)		4	1.3	1.2	1.4
/8 surface area - lake (acres)			3900	4600	5500
stream (acres)			5400	0	0
access - fresh (1000 acres)			0.07	0.07	0.07
salt (1000 acres)			0.4	0.5	0.6
anadromous (1000 acres)			0.06	0.02	0.03
piers - (1,000 feet)			11	15	18
wildlife - hunting (1000 man-days)		2.3	0.2	0.9	1.9
other (1000 man-days)		2.2	0.1	0.2	0.2
Liquid Waste Disposal (million PE of untreated waste)		3.7	8.8	20.0	43.2
Flood Control: (average annual damage - million dollars)					
upstream		1.9	2.9	5.4	10.5
mainstem /5		3.6	6.2	12.5	26.2
major storm drainage					
coastal					
Drainage: cropland (1,000 acres)		45	22	22	0
/4 forest land (1,000 acres)		0	0	15	15
meadow land (acres)		0	0	0	0
Erosion: agriculture (1,000 acres)		1720	2226	2958	3511
urban (1,000 acres)		201	205	286	413
river bank (miles)					
shoreline (miles)			3	0	0
Health: vector control			X	X	X
pollution control			X	X	X
Visual & Cultural: /4					
landscape maintenance - unique natural (square miles)			80	0	0
unique shoreline (miles)			80	0	0
unique cultural (number of sites)		37	37	0	0
high quality (square miles)					
diversity (square miles)					
agriculture (square miles)					
clean water (percent of area)			10	0	0
metropolitan amenities (sq.mi.)			11	0	0
landscape development - quality (square miles)					
diversity (square miles)					
Legal: Laws for water allocation;					

TABLE - 2 /7
DEVICES /6

	Purposes	Number or Quantity 1980	2000	2020
I. Resource Management				
A. Water				
Storage Facilities (1,000 acre feet)				
reservoir - upstream	MI, Ind, Ir, Rec, FW, FC, LW.	300	300	270
mainstem & major tributaries	MI,Hyd,Rec,FW,FC, LW.	730	0	0
ground				
Withdrawal Facilities				
river intakes	MI,Ind,Hyd,Irr.	X	X	X
lake intakes	MI,Ind.	X	X	X
estuarine intakes	Pow.	X	X	X
ocean intakes	Pow.	X	X	X
wells (mgd)	MI,Ind,Rur,Irr.	66	180	363
Conveyance Facilities				
diversion - intrabasin (mgd)	MI.	X	X	X
interbasin (mgd)	MI.	X	X	X
tunnels				
pipeline	MI.	X	X	X
aqueducts & channels	MI.	X	X	X
pumping stations	MI,Ind,Hyd.	X	X	X
Quality Control Facilities				
temperature - cooling towers	Pow, Liq Waste.	X	X	X
cooling ponds				
chemical/biological -				
treatment plants (water) mgd	MI,Health.	16	75	143
secondary (85%) 10^6 PE residual	Lq Wst.	1.3	0	0
secondary (90%) " " "	Lq Wst.	0	1.9	4.2
advanced (95%) " " "	Lq Wst.	0	0.1	0.1
nutrient control	Lq Wst.	X	X	X
stormwater discharge control	Lq Wst.	X	X	X
acid mine drainage control				
septic tank control				
separate combined sewers	Lq Wst.	X	X	X
Monitoring Facilities				
B. Water/Land				
Flood Plain Management - upstream (1,000 acres)	FC.	51	127	10
mainstem " " /5	FC.	X	X	X
Local Flood Protection - ocean				
river (projects)	FC.	3	0	0
intra-urban				
Watershed Management	Dr,FC.	X	X	X
Conservation Treatment (acres)	Erosion.	510	813	680
Shore Erosion Protection - ocean	Rec.	X	X	X
river				
Waterway Management - channel improvement				
upstream	Dr.	X	X	X
mainstem /5	FC,Nav,Rec.	X	X	X
harbor improvement	Nav.	X	X	0
lock rehabilitation				
obstruction removal				
breakwater & jetty				
offshore facilities				
navigation aids				
lightering				
cargo diversion				

TABLE - 2 (continued)

DEVICES	Purposes	Number or Quantity 1980	2000	2020
C. Land				
Acquisition (miles/square miles)				
fee simple purchase (buying)	VC.	80/91	%	%
purchase lease				
easements				
deed restrictions				
tax incentive subsidy				
zoning				
Access				
overland transportation to facility	Rec.	x	x	x
parking and trails	FW, Rec.	x	x	x
D. Ecological				
Habitat Management - fish	FW.	x	x	x
wildlife	FW.	x	x	x
Fishways	FW.	x	x	x
Stocking - fish	FW.	x	x	x
wildlife				
E. Human/Environment				
Insect Control	Health	x	x	x
Site Facilities				
Legal - interstate agreements	MI, FC.			
constitutional amendments				
international agreements				
legislation	MI, FC.			
institutional arrangements				
II. Research	Lig Waste	x	x	x
III. Education	General	x	x	x
IV. Demand Changes				
Pricing				
Rationing				
Remove Legal Restriction	FW, Rec.	x	x	x
Non-condenser Power Facilities				
Re-circulation (internal)				
Reuse (basin factor)				
Change Project - expand	Rec.	x	x	x
remove	FW.	x	x	x
add new need	Rec, FW.	x	x	x
change design load	Rec.	x	x	x
Water Quality Standards - raise				
lower				
enforce them	VC, Health, MI, FW, Rec.	x	x	x

TABLE - 3 /7

COSTS
(millions of dollars)

Needs	First Costs 1980	First Costs 2000	First Costs 2020	OMR	Present Value	Average Annual
Municipal and Industrial: surface	25.1	38.8	42.0			
ground	1.0	1.8	2.3			
Industrial Process and Cooling	8	25	55			
Rural ($1,000)	1.7	3.3	1.4			
Irrigation: agriculture	5.6	11.2	3.7			
non-agriculture	6.7	5.5	7.4			
Power Cooling (additional for objective)	0	52	110			
Hydroelectric						
Navigation: commercial	40	11	0			
recreational	4	4	4			
Recreation	15	80	100			
Fish and Wildlife	2.2	2.2	2.5			
Liquid Waste Disposal: secondary	495	1120	2,420			
advanced	0	7	11			
Flood Control:						
upstream	28	22	19			
mainstem /5	29.6	0	0			
Drainage	1.4	1.9	1.5			
Erosion	41.6	63.1	55			
Health						
Visual and Cultural	25.5	0	0			

Notes for Tables

/1 recreational boating costs are included under recreation access costs.

/2 1980 includes present demands; 2000 and 2020 are incremental unmet demand figures.

/3 surface acres overlap with other storage needs and also include the opening of present water supply reservoirs to recreation.

/4 the "Present" figures are totals while the benchmark year figures are increments.

/5 all mainstem figures include major tributaries.

/6 devices are incremental and will include, in future lists, farm impoundments, and effluent irrigation.

/7 numbers on these Tables will change at least some during the next two months and in some cases there will be significant changes.

/8 the "Present" figures are totals while the benchmark year figures are incremental unmet demands.

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IN REPLY REFER TO

PLAN FORMULATION MEMORANDUM 20
TO MEMBERS OF THE AD HOC WORK GROUP ON PLAN FORMULATION
NORTH ATLANTIC REGIONAL WATER RESOURCES STUDY

24 November 1971

Reference is made to Plan Formulation Memorandum 19 dated 5 November 1971 announcing a meeting of the Work Group at the North Atlantic Division Office, on 7 December 1971.

The following reference material on the supply model is inclosed:

1. Notes on the NAR Supply Model
2. Schematic Diagram of Supply Model Results
3. Supply Model Cummulative Development and Cost Totals (3pgs.)
4. Supply Model Transfer Costs
5. Supply Model Mixed Objective Demands (9 pgs.)
6. Net Water Demands (5 pgs.)
7. Mixed Objective Water Withdrawal Plan
8. Mixed Objective Gross Demands
9. Reservoir Storage based on Supply Model Results

It is requested that members review the inclosures before 7 December 1971 in order to facilitate the assessment of the criteria and results at the meeting. This will help assure that there is time for discussion of the incorporation of supply model data in Area and Regional Programs and other matters.

Eugene T. Fleming Jr.
for HARRY E. SCHWARZ
Chairman
Plan Formulation Work Group

Incl
As stated

CHAPTER 6

DEMAND MODEL

INTRODUCTION TO THE DEMAND MODEL

The demand model contains assumptions about gross national product, personal income, population, distribution of economic activity and water withdrawal (technologic) coefficients and converts these, through an information system, into estimates of withdrawal requirements for fresh, brackish and waste water and consumption of fresh water. These estimates can be printed out by areas and subareas, and by state or other political boundaries depending upon input instruction. The information system that is at the heart of the model is composed of an economic input-output table for the NAR derived from national inter-industry flow coefficients; a regression estimate of muncipal water demand derived from Connecticut times series data; and numerous arithmetic operations. The system was developed and programmed by the NAR staff and water resources planners at the Massachusetts Institute of Technology for flexible and easy use. Agencies and states, as a result, can run the model themselves using their own assumptions. The model can be adapted for other regions where an input-output table is available, and also used, is modified form, where certain other types of projections models are available.

Estimates of demand for different objectives have been made on the basis of alternative assumptions about the input parameters appropriate to each of the Study objectives. For the regional development objective, for example, assumptions of higher productivity have been used thant for the other objectives. Alternatives input assumptions have also been made in ways not directly linked with objectives in order to provide some idea of the possible range of water requirements in the Region. A typical change of this sort is a reduction in water use that might be obtained through technological progress.

A "compare" routine is an important feature of the demand model (and of the supply model as well). This routine is a compture option that enables planners to calcalulate the differences in water requirements (or, for the supply model, in costs and sources) resulting from any two sets of input data. This capability is useful in enabling decision-makers to see quickly the consequences of a change in assumptions relating to, for example, technology or population growth.

THE INPUT - OUTPUT MODEL FOR
ESTIMATING WATER DEMAND

The most important mathematical relationships in the demand model are those of the regional input-output model. This model was investigated following the adoption of the multiobjective approach to plan formulation; the paper that follows, describing the use of regional input-output models for estimating water requirements, was presented at the Sixth Meeting of the Coordinating Committee, held 22-23 May, 1968 at Cherry Hill, New Jersey.

Following this paper, a detailed discussion of the formulation of the demand model as a whole, including the regional input-output table, is presented. This discussion is taken from the first four chapters of NAR Special Publication #1, "Users Manual and Detailed Description, Regional Water Demand Information System".

We will review a modification of the national input-output model that yields a regional input-output model for estimating industrial, agricultural, and commercial water use. This model has been developed by a group working at the University of California at Berkeley.

To demonstrate the usefulness of this model, we will review briefly the nature of input-output in general, the conversion of the national matrix to a regional matrix, and the purposes to which this technique can be devoted.

Input-output is a simplified method for picturing the interactions of an economy broken down into producing sectors. Although the underlying production theory is very simple (inputs are assumed to be proportional to outputs), the construction of a table is ordinarily very expensive and time consuming. For example, we were told some time ago that the direct construction of a table for the NAR might cost several millions of dollars and take several years. The method that we will discuss today represents a considerable scaling down of that estimate.

For the United States as a whole the input-output table currently available is for the year 1958. This table has 81 sectors. A new table is being prepared by the government for the year 1963. This table should have about 350 sectors, a great increase in detail. (Something of the nature of the detail is illustrated by the fact that a preliminary breakdown of sectors recently made available showed as separate industries: tanks and tank parts, and morticians goods).

We have with us the input-output table published by Scientific American for a hypothetical gross national product of 750 billion dollars at 1958 prices. The interindustry relations in this table are based on

the 1958 table. As a matter of fact, the GNP in 1967 exceeded 750 billion dollars at 1958 prices so that this is a picture of a table that is somewhat outdated both as to totals and as to interindustry relationships. The table gives a picture of the flows in the economy from one sector to another as well as a picture of the gross national product accounting scheme.

One can focus on several important parts of the table. The first is the large interindustry flow matrix which shows all flows from one industry to another in dollar terms and in coefficients that will be explained in a moment. Each small box (including the small colored boxes) represents transactions from one supply industry, as supplier, to one industry, as user. A group of columns to the right is the final demand group (that is, the sectors that compose GNP on the output side); a group of rows on the botton is the value added group (that is, payments to factors of production and certain other payments; these payments add up to the gross national product on the income account). Furthest to the right is a single column which indicates the gross output of every industry; namely, the sum of outputs to other industries and to final demand. The key differences between the information available on this table and in the GNP accounts are, first, the existence of the interindustry sector, and, second, the gross output column.

Figure 3 depicts two of the small interindustry boxes in order to show more clearly the information available in the interindustry matrix. The small numbers on the outside of the boxes refer to the numbers of the industries in question in the input-output scheme. Number eight is the food industry, number 60 is chemicals, and number 40 is primary iron and steel. In the figure, the iron and steel industry is the supplying industry, and food and chemicals are the user industries. Steel, of course, is also a supply industry to the steel industry; however we have not shown this box. (In the complete table every industry is shown as a supplier and as a user). The largest of the three figures in each box represents millions of dollars in flows from the supplier and as a user). The largest of the three figures in each box represents millions of dollars in flows from the supplier to the user. This is the number of millions of dollars of output of the steel industry bought by the food industry and the chemical industry for a hypothetical GNP of $750 billion. The small figures in the left hand corner of the boxes represent the number of dollars spent on the input of the supplying industry per thousand dollars of user industry gross output. In other words, if the user industry spent 1% of its total revenue on the supplying industry, it would be spending $10 per thousand; the figure in the lower left hand corner would then be 10. It is conventional in such tables to color in a box that represents more than 1 percent of direct input.

The small figure in the lower right hand corner of each box represents one of the most remarkable aspects of input-output economics. This figure represents the total amount of the supply industry's production which is required to produce $1 in final demand output of the user industry. This figure is in

cents per dollar. As a percent, it's always at least equal to and generally greater than the figure in the lower left hand box. The food industry, for example, uses little steel and iron as a direct input, but the other industries supplying to the food industry use iron and steel in producing their own outputs. All of this steel is indirectly required to produce an additional dollars' worth of food for final demand, and it is included in the coefficient on the right in addition to the steel and iron used directly by the food industry. This coefficient is called the "inverse" coefficient after its mathematical significance. This coefficient has important uses: for example; in a war time planning situation one could estimate directly from his coefficient the amounts of steel required to produce, say, 100 airplanes. By examining all of the inverse coefficients in the table one can estimate the total of all commodities that would be required to produce a certain bill of final demand, that is, a certain GNP. It is this use that is relevant to our planning efforts.

To produce a regional flow table from the national table information on regional final demand and gross output must be developed. This is applied to the national table in a computer program developed at Berkeley; and the result is a table of regional industrial flows. This method of deriving a regional table should be reasonably free of gross erros if the region in question is sufficiently similar to the national economy. This is true of the NAR, in which a large fraction of GNP is produced. When the regional industrial flow table has been generated, water use coefficients can be substituted for the industrial flow coefficients by a simple process of multiplication. If we know that an industry uses on the average a certain number of acre-feet of water per million dollars of output, we can apply this figure to the industrial coefficients in the regional input-output table to derive water flow coefficients. One further modification of the table is entailed in this process. Since good water use coefficients are not available for all industries at the level of disaggregation shown in the table, the sectors of the table are aggregated as required.

As a final result of these operations, we have a regional input-output table expressed entirely in terms of water use coefficients. With this table, one can estimate the total water use required to increase the output of any industry to final demand; more important, one can estimate the entire gross water demand in the NAR of industry, commerce, and agriculture implied by any bill of final demand.

This a remarkable result, for it permits rapid calculation of gross water needs on the basis of alternative assumptions about regional demand; given the assumptions of the regional input-output table, moreover, the calculations of gross water needs for each sector are consistent with each other. This consistency should prove to be an important check on our other methods of estimating water demand. We expect to use the input-output technique to gain insight into the water planning problem for the NAR in several ways. First, the table will enable us to calculate quickly the water requirements not only of the OBE guideline projections but of other GNP projections as well. Second since emphasis on alternative objectives should imply different compositions of regional final demand we should be able to explore water demans for different objective mixes. Finally, by varying the water coefficients, we can explore the effects on gross water demands of changing technology.

There are some extensions of this method that may prove fruitful. One is the application of the national-regional conversion method to produce tables for each of the six major NAR planning regions. A second is the application of linear programming to the table, assuming that water is a constraint on development, to drive an implied value for an acre-foot of water in the region.

The use of this input-output method in the NAR has a number of significant limitations. First, the water demands that can be calculated are limited to the gross demands of industry, agriculture, and commerce. The model does not yield estimates of household demand, demand for municipal uses, or demand for water in place (recreation) or for the restraint of water (flood control). In addition, the method suffers from fixed coefficients, from outdated coefficients, from the application of water use coefficients that may not apply accurately to the interindustry coefficients of a table produced in an earlier year, and from the inaccuracies resulting from the conversion of the national table into a regional table.

In using this tool we will always have to be aware of these limitations, in order to avoid imputing more validity to the results of applying the method than these results warrant. All things considered, however, we think that the use of the input-output table for regional water demand estimation will yield results whose benefits significantly exceed the costs of adapting the national table to the NAR.

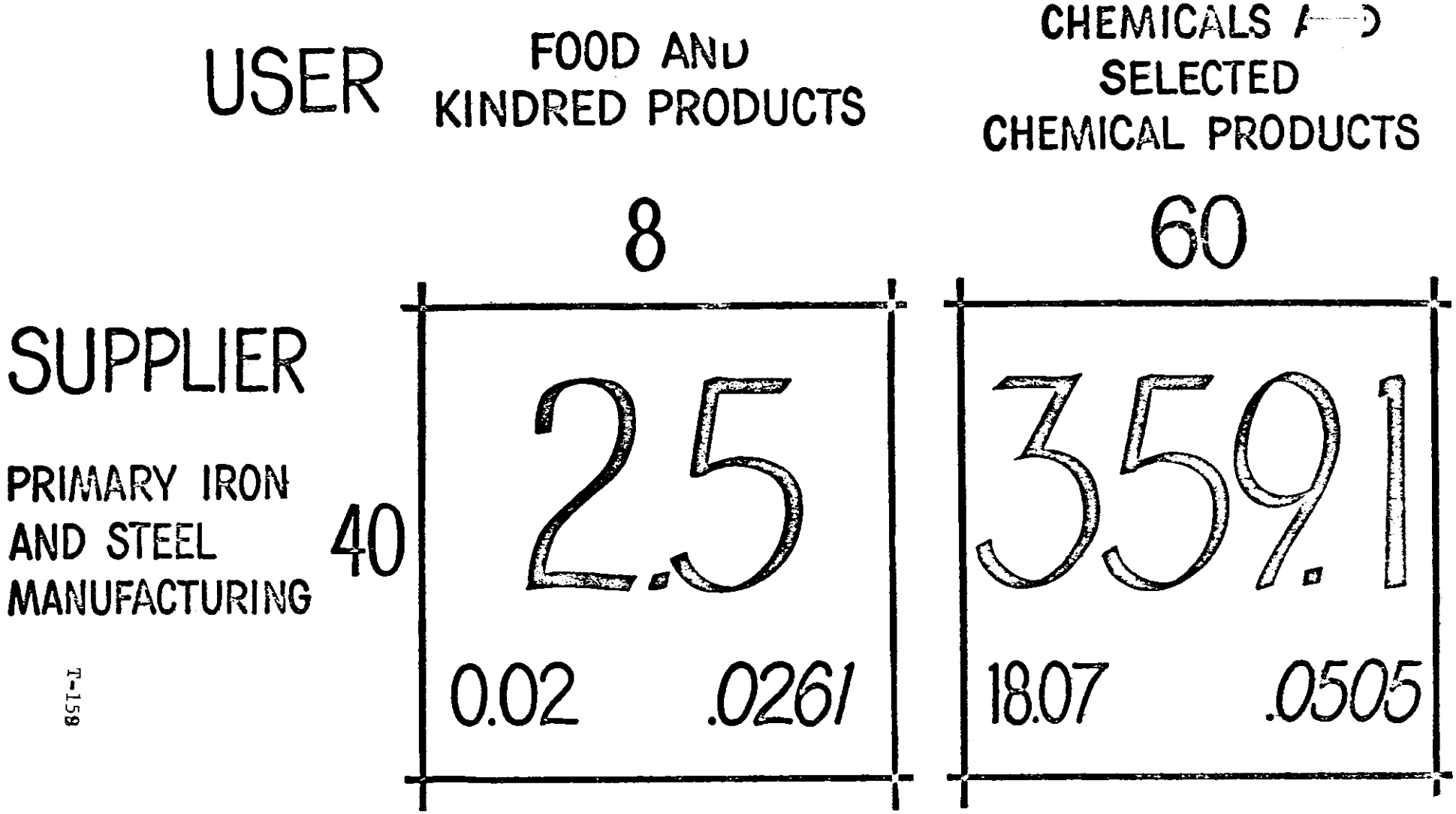

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FIGURE 3

DESCRIPTION AND FORMULATION OF THE MODEL

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Users Manual and Detailed Description

Regional Water Demand Information System

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Prepared for

North Atlantic Regional Water Resources Study

U.S. Army Corps of Engineers

North Atlantic Division

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(NOTE: ONLY CHAPTERS 1-4 INCLUDED IN APPDX. T)

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1.0 Introduction

The demand model is an "information system" which allows the user to obtain estimates of the water demands or requirements that would exist according to certain assumptions and relationships between these assumptions. The initial assumptions are made by the user who then gives these to the model in the form of input data. The relationships between these assumptions have been programmed as part of the demand model. The model accepts the input data, performs the desired calculations, and outputs results as requested by the user.

The adequacy of the system may be judged in terms of (i) the appropriateness of the assumptions used, (ii) the appropriateness of the relationships used, and (iii) the ease with which those interested in the results can give access to the model. User access to each of the many special features of this system is provided through problem-oriented statements that cause the system to accept input data, perform computations, output results, store data, retrieve data, etc. as the user may require.

The output of this model is a set of estimates of water flow requirements for different geographical areas, economic sectors and water quality types. These estimates are generated by utilizing a collection of rules for converting basic assumptions into these estimates. The assumptions have to do with GNP, income, population, technology, distribution of economic activity and water use. The collection of rules for converting these assumptions into estimates include an input-output (I-O) model, a regression estimator of publicly supplied municipal and industrial (M&I) water demand, and some simple arithmetic operations.

It is important to put the demand model in perspective as a planning tool. First, and perhaps most important, the model is basically a flow demand model. Since many planning variables other than flow are important in any water resources study (for example,acres of surface area for recreation, flood damage estimates, and many others) the model as it now stands does not in itself comprise a total planning system. It must be supplemented with information derived by other methods. On the other hand, any part of the planning operation that can be approximated by a set of systematic relationships could be attached to the model as an additional part of the information system. Nevertheless, as it now stands, the model is a flow demand model and not more.

Second, the use of this information system does not constitute a method of planning completely different from previous river basin approaches. In fact, the system performs basically the same kind of operations on information that have been performed in past river basin plans. The advantage in using the model are speed, the ability to examine alternatives rapidly and, perhaps not least, the careful setting forth of assumptions. There are parts of the model that have not usually been used, such as the I-O and regression estimator; but, fundamentally the model is an extension of previous river basin planning efforts.

Third, the model, in common with almost all such systems, suffers from the mathematical property of linearity (for

example, making one thing directly proportional to another). Since the world is not linear (although often approximately so) all such models have to be used with a recognition of this particular limitation. However, as mentioned, this limitation is shared by this and most models, and, indeed, most traditional river basin planning efforts.

Forth, the data requirements of the model offer a structure for organizing data collection activities since the required input information is clearly specified. Data collection is always one of the largest tasks in water resource planning, and the demand model does not really change this fact. As with previous planning techniques, the task of preparing a set of basic data (which subsequently may be altered to reflect different assumptions) is formidable and easily underestimated.

1.1 User's Manual Organization and Use

This manual is designed to provide information to the user regarding the basic assumptions he must make (input data requirements), the relations between these assumptions which are used by the model, the format of the output, and the control of the system by the user. Seperate sections on each of these are provided.

The next sections, General Description of the Demand Model and the User-Oriented Information System Environment is provided to give the user an over-view of how the complete system works and what it does, both from operational and computational

viewpoints. This model does not function like a typical computer program because the user retains complete control of the sequence of operations that are performed.

Following are sections on input data, detailed description of the computations and a section on user control of the system. The latter section describes how each individual "command" functions, and it also explains how different commands can be used together to achieve a desired result. The ideas in each of these sections (3 to 5) are illustrated in section 6 where a sample problem appears. The sample problem has been designed to point out most of the capabilities of the model.

This manual has been divided into two parts. All of the previously mentioned sections comprise Part I, Users Manual. The second part, Part II, Detailed Description is provided to give the user who may be interested, a detailed account of the structure and function of the computer program.

2.0 General Description of the Demand Model and the User-Oriented Information System Environment

This demand model is written in the FORTRAN language, but it is not typical of most other FORTRAN programs. It is different from most programs because the user controls program operation by giving "commands" to the system, the system executes the user's command and then the system expects to receive another command. In one important respect, however, the system is typical of other programs. There are a set of computations to be preformed on a set of input data, and a set of results are produced, as in most other programs. The uniqueness of this system lies in the way in which the input of data and the output of results are handled, including features which allow the user to edit data, to compare results from different runs, to easily and quickly change any part of the data, and to store complete data sets for subsequent use.

2.1 The Demand Model

The purpose of the model is to estimate future water requirements for use in water resourse planning studies. Water requirements for fresh water, waste water, brackish water and consumptive use in different geographical locations and economic sectors may be estimated. These estimates are based on projections or assumptions of quantities such as gross national product, personal income, population, technological water use coefficients and the distribution of population, income and economic activity.

The rules which are used to combine the information given as input are based primarily on an economic input-output model and on a regression model for publicly supplied municipal and industrial use. Other simple arithmetic operations are also provided. Information from Department of Agriculture Water Supply studies and Federal Power Commission may be given directly as input data and used to control water use estimates in agricultural and power cooling sectors.

The general sequence of model operations during a typical run are illustrated in Figure 2-1. The first step is to get all of the input data into the computer. This is done under user control by use of the different commands that cause the stystem to accept input data. The second step is to "execute" the model; that is, to calculate the estimated water requirements. These are the calculations which are required by the input-output model, the M&I regression model, etc. The final step is to print-out the results. This may be done selectively (any part of the complete set of output can be obtained) or a complete set of output may be requested (for the NAR study this is 250 pages).

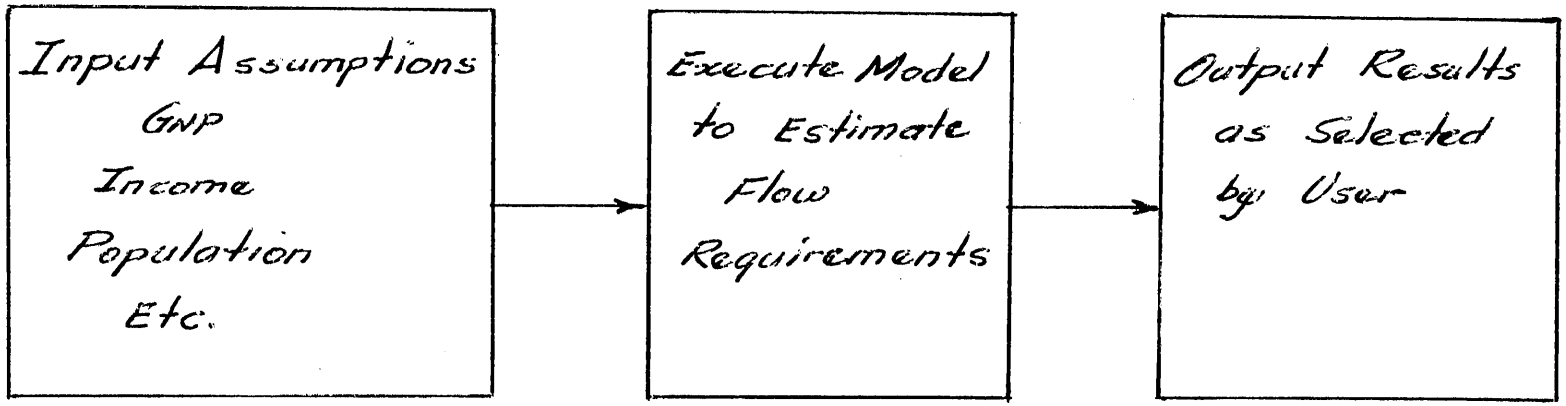

Figure 2-1 General Sequence of Operations During a Typical Run

The demand model consists of 6 sub-models. These are illustrated in Fig. 2-2 and are described briefly below.

Subroutine MUNWAS - Estimates publicly supplied M&I use on basis of assumptions of population, per capita income, population and income distribution. A regression model is used to make the water use estimates on the basis of this information.

Subroutine INDACT - Estimates gross output by sector in each sub-basin on the basis of assumptions of GNP, and distribution of economic activity. An Input-Output (I-0) model is indeed used, and this requires an I-0 inverse coefficient matrix which may be based on national I-0 data.

Subroutine RURWAS - Estimate gross rural domestic use of basis of assumptions concerning rural population and per capita rural domestic use.

Subroutine GROSSW - Estimates gross water use by sector and by sub-basin. Estimates are based on technological water use coefficients which transfer $ gross output into mgd of water use in each sector except M&I and Rural Domestic.

Subroutine CONST - This routine permits the user to modify water use estimates according to the I-0 model in the agricultural sectors. The modifications are based on assumptions from Dept of Agriculture studies. This feature is provided because the technological water coefficients for the agricultural sectors may not be very dependable. If DA data are substituted for estimates based on the I-0 data, the implied technological water use coefficient is printed out.

Subroutine Power - Similar to subroutine CONST, this routine permits the user to modify water use estimates done by the Federal Power Commission.

Subroutine NETW - This routine combines water use estimates in different sectors of a sub-basin and accounts for possible re-use within the sub-basin. The results are estimates of the water use by water use category and by water quality.

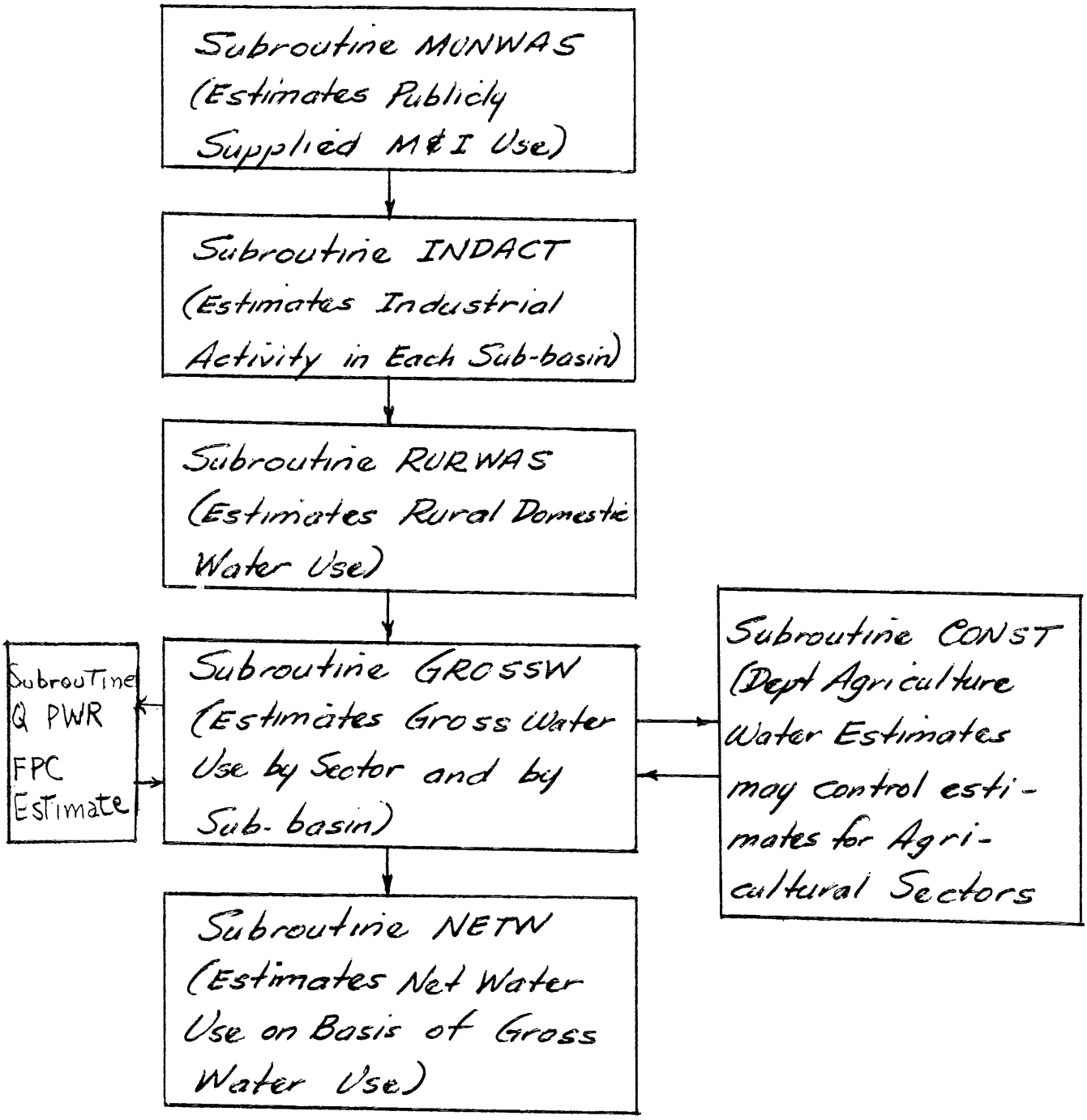

Figure 2-2 General Structure of the Demand Model

2.2 The Information System

The system has been designed so that operation of the mathematical water demand model, the input of information to the model, the output of information from the model and the storage and retrieval of information from data tapes are completely controlled by the user. The user controls the sequence of system operations through the use of "commands" which are input to the system. A so-called command is punched on a data card. The system reads this card and sets-up the necessry instructions to execute the command. Certain commands require additional data cards so these are placed directly behind the command card that requires them. A command card, together with any required data cards for that command is called a command information set. The system will accept any sequence of command information sets that the user may provide. Then the systems capabilities are determined not only by the individual commands that the system can execute, but also by the more complex operations which may require a sequence of basic commands.

In the event there is a discrepancy between the number of data cards actually provided in a command information set and the number that the system expected, the system will not execute that command and will continue to read data cards until it recognized the next valid command. Thereupon, the normal operation will be resumed.

This mode of operation is not typical of conventional FORTRAN program operation so the general structure of the

system is not typical of other programs as well. Actually, two different people could use the system to solve identical problems using different sequences of commands. Therefore, the sequence of operations performed is each case would be different. For this reason, it is not possible to draw a conventional flow chart of the entire system. However, it is possible to draw a diagram illustrating the over-all structure of the system as shown in Fig. 2-3.

The key component in the system for coordinating its operation is the Main Program. This component reads input cards which are interpreted by it to be command cards (Note in Fig. 2-3 that the main program block is connected to the block labeled command cards by a double arrow. One direction of the double arrow represents the act initiated by the main program of requesting a command card from the stream of input data cards. The other direction represents the transfer of information from the card to the main program.

When a valid command is recognized, the Main Program sets-up proper linkages with the subroutines required to carry out that command. The possible linkage to other subroutines appear graphically in Fig. 2-3. The arrows in that figure denote transfer of information or transfer of control. Double arrows appear everywhere because all of the loops in this system are closed loops.

The principal sub-systems illustrated in Fig. 2-3 are

Subroutine CARDS - which reads input data from data cards as required by the various INPUT...commands.

Subroutine OUTPT - which prepares the output of results according to special formats.

Subroutine S300 - which refers to the proper entry of subroutine OUTPT to give the results desired by the user.

Subroutine TAPES - which processes data to and from the data tapes.

Subroutine COMP - which computes the change from one run to another.

Subroutine MODEL - which performs the demand model computations.

Fig, 2-3 may help the user to understand how the system functions. Beginning at the top, the system recognizes a <u>command card</u> that the user placed in the input deck. (The first card of the input deck must necessarily be a command card.) The main program then determines which of the principal subroutines is to be called to execute that command. (These are multiple-entry routines which means there is more than entry point and each entry has a unique name descriptive of the function performed starting at that entry.) When the subroutines have completed their mission, they return control to the higher level. Eventually, control is returned to the user and the system expects another command card.

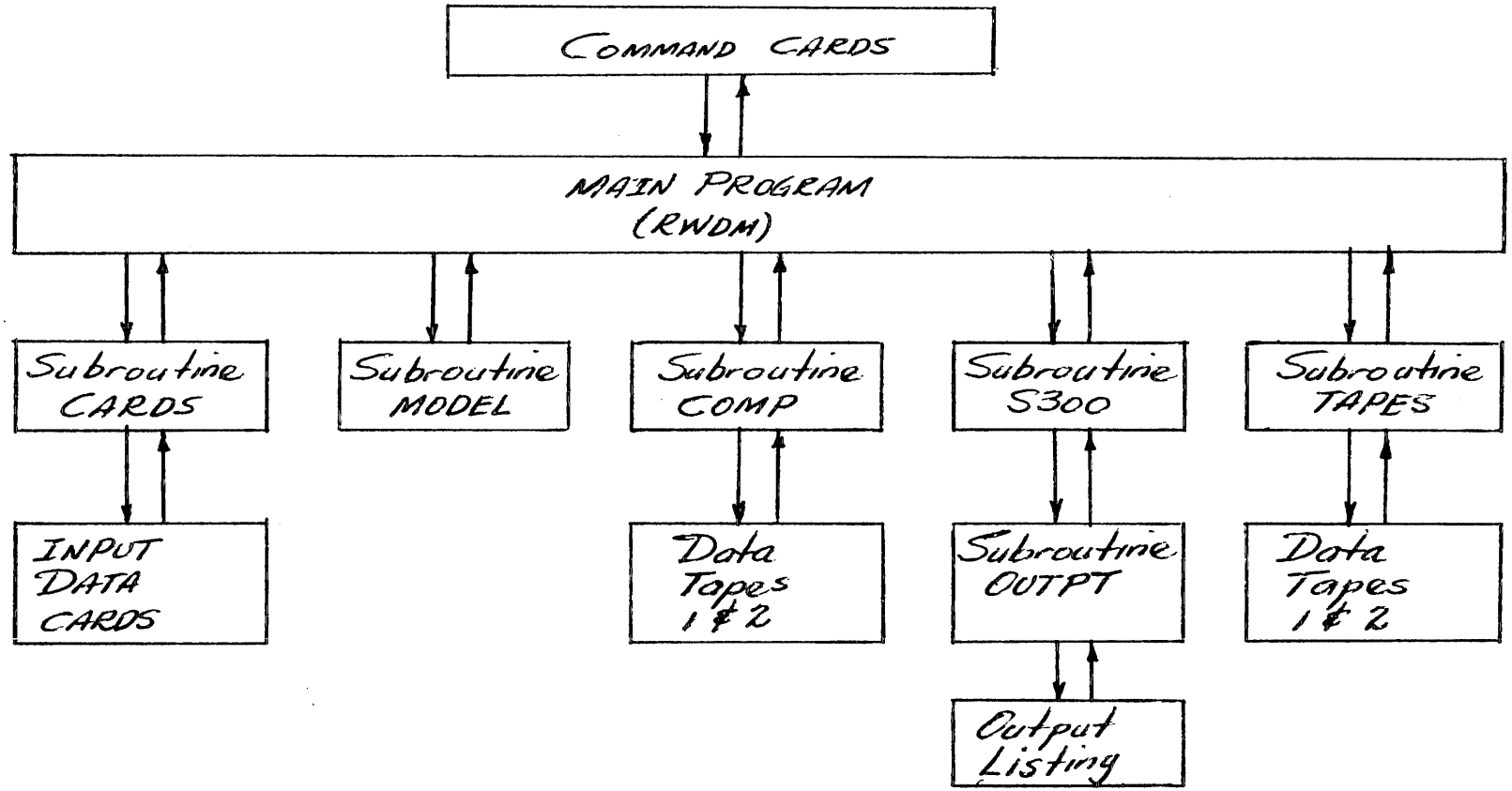

Figure 2-3 General Structure of the Information System

3.0 Summary of Input Data Requirements

The purpose of this section is to serve as a checklist of the data requirements. It is provided to call the user's attention to the specific items of information needed or to the specific assumptions that must be made. As one becomes familiar with the model and the names of the arrays in which the input data are stored, it will likely become more convenient to use the lists of valid variable names in section 5.1 as a check-list rather than this section.

3.1 Control Information

Initially, certain basic control information is required such as the number of river basins in the region, the total number of sub-basins in the region, etc. These data are described in sections 5.1.5 and 5.1.7.

3.2 Municipal Water Use

Required input data for publicly supplied municipal and industrial water calculations include estimates of municipally served population for each river basin, population distribution among the sub-basins, per capita income in each river basin, sub-basin/river-basin per capita income ratio for each sub-basin, base value of M&I use in each sub-basin, and the elasticities of M&I use to population change and to income change. the elasticities are pre-set as "default" values, and these values are used unless the user specifies different values. (See also sections 4.1.2 and 5.2).

3.3 Industrial Economic Activity

Required input data for industrial economic activity calculations include the I-O regional inverse coefficient matrix, estimates of GNP and proportion of GNP in the region, distribution of final demand (GNP) among the sectors, and the distribution of each sector's economic activity among the sub-basins. (See also sections 4.2.5 and 5.2)

3.4 Rural Domestic Water

Required input data for rural domestic water calculations include estimates of total population in each river basin, distribution of total population among the sub-basins, rural per capita domestic use and the municipally served population information which also is required for the M&I calculations. (See also sections 4.3.2 and 5.2.)

3.5 Gross Water Use and Net Water Use

Required input data for gross water use calculations include the technological water use coefficients (gal of water per $ output in each sector, in each sub-basin and by type of water quality), proportion of publicly supplied industrial water in each sector in each sub-basin, distribution of municipal withdrawal according to water quality, distribution of rural withdrawal by water quality. The user may also wish to provide information from Department of Agriculture water supply studies, including: agricultural water requirements (non-irrigation use) in each sub-basin; crop irrigation requirements in each sub-basin; other irrigation requirements in each sub-basin.

Net water use calculations require the following data: proportion of crop irrigation not assigned to ground water; proportion of non-irrigation agricultural supply not assigned to ground water;proportion of non-crop irrigation not assigned to ground water; and sub-basin re-use coefficients for M&I withdrawals, industrial water use and power cooling. (See also sections 4.4.5, 4.5.2 and 5.2.)

4. Detailed Description of the Demand Model

The function of the demand model (which must be distinguished from the information system environment in which it operates) is to compute the new water demands that are implied by the set of input data that results from given assumptions about the factors which may affect net water demands. The calculations may be grouped into the categories of Municipal Water Use, Industrial Economic Activity, Rural Domestic Water Use and Gross Water Use Calculations. The gross water use is transformed into net water use by accounting for re-use within any one water use category that may occur in any one sub-basin.

4.1. Municipal Water Calculations

Municipal withdrawals are made by municipalities to supply domestic, commercial, and some industrial requirements. To account for this in the model, the total municipal withdrawals are computed in subroutine MUNWAS for each sub-basin.

The governing relationship was derived from a regression analysis of time series data for municipal withdrawal as a function of population and per capita income. The regression equation has the form

```
MWU(J) = A(J)*(DPOP(J)**B1)*(DY(J)**BZ)
```

where

MWU(J) = municipal withdrawal (MGD) in sub-basin J in target year

DPOP(J) = population (in thousands) in sub-basin J in target year

DY(J) = per capita income (in $) in sub-basin J in target year

B1 = elasticity of municipal withdrawal to population change

B2 = elasticity of municipal withdrawal to income change

A(J) = a constant which depends on the base data withdrawal, population and per capita income

The constant A(J) is computed as

$$A(J) = \frac{BMWU(J)}{(BDPOP(J)**B1)*(BDY(J)**B2)}$$

where

BMWU(J) = municipal withdrawal (in MGD) in sub-basin J in the base year

BDPOP(J) = population (in thousands) in sub-basin J in the base year

BDY(J) = per capita income (in $) in sub-basin J in the target year.

4.1.1 Calculation of Sub-basin Population and Per Capita Income

The sub-basin population quantities DPOP(J) and BDPOP(J) as well as the sub-basin per capita income quantities DY(J) and BDY(J) are derived from population and per capita income data for the respective river basins. The equations are

DPOP(J) = POP(L)*DISTP(J)

BDPOP(J) = BPOP(L)*BDISTP(J)

DY(J) = Y(L)*DISTY(J)

BDY(J) = BY(L)*BDISTY(J)

where

POP(L) = population (in thousands) in river basin L (which contains sub-basin J) in target year

BPOP(L) = population (in thousands) in river basin L (which contains sub-basin J) in the base year

Y(L) = per capita income (in $) in river basin L (which contains sub-basin J) in the target year

BY(L) = per capita income (in $) in river basin L (which contains sub-basin J) in the base year

DISTP(J) = proportion of total population of river basin L in sub-basin J in the target year

BDISTP(J) = Proportion of total population of river basin L in sub-basin J in the base year

DISTY(J) = ratio of per capita income in sub-basin J to per capita income in river basin L in target year

BDIST(J) = ratio of per capita income in sub-basin J to per capita income in river basin L in base year

4.1.2 Required Data Input for Municipal Water Calculations

Required data input to the model for municipal water calculation consists of the vectors BMWU, POP, BPOP, Y, BY, DISTP, BDISTP, DISTY, BDISTY and the scaler elasticities B1 and B2. A default option is built-in which sets B1 = .825 and B2 = .308 if other values are not explicitly specified by the user.

4.2 Industrial Economic Activity

Industrial water requirements are estimated on the basis of an economic input-output model of economic activity together with technological coefficients which relate economic activity and the water requirements of that activity.

Industrial economic activity is accounted for in subroutine INDACT. This subroutine determines the gross output vector of each sub-basin on the basis of an input-output model. The sub-basin gross output vectors are subsequently used in subroutine GROSSW for calculation of gross industrial water requirements in each sub-basin.

4.2.1 Sub-basin Gross Output Calculations

The relations for computing the sub-basin gross output vector in subroutine INDACT are as follows.

$$SBGOV(I,J) = GOV(I)*SSAM(I,J)$$

where

SBGOV(I,J) = gross output (in $ millions) for sector I in sub-basin J in the target year

GOV(I) = gross output (in $ millions) for sector I in the entire region in the target year

SSAM(I,J) = proportion of the regional economic activity in sector I that takes place in sub-basin J in the target year

Industrial activity in as many as 39 sectors may be handled by the model.

4.2.2 Regional Gross Output Calculations

The gross output vector GOV(I) is computed from the regional inverse coefficient matrix, RICM, according to

$$GOV(I) = \sum_{M=1}^{NSEC} RICM(I,M)FDV(M)$$

in which

RICM(I,M) = $ of output from sector I required by sector M in order for sector M to add a one $ increment to GNP in the target year

FDV(M) = final demand ($ millions) for the output of sector M. (This is the part of the output from sector M that is directly consumed and is also the total contribution of sector M to GNP, in the region in the target year.

4.2.3 Regional Final Demand Vector

The final demand vector is computed according to

FDV(I) = GRP*RFDDV(I)

where

GRP = gross regional product ($millions) in the target year

RFDDV(I) = regional final demand distribution vector which specifies the proportion of the GRP produced by sector I in the target year

4.2.4 Gross Regional Product

The gross regional product is computed as

GRP = PGNP*GNP*1000

where

GNP = gross national product (in $ billions) in the target year

PGNP = proportion of the GNP in the region in in the target year

4.2.5 Required Data Input for Industrial Economic Activity

Required data input to the model for industrial economic activity calculations consists of: the arrays RICM and SSAM; the vector RFDDV; and, the scalors PGNP and GNP.

4.3. Rural Domestic Water Calculations

The water requirements for rural domestic use are estimated on the basis of rural population and a rural per

capita water use coefficient. The controlling relation is

RWU(J) = DRPOP(J)*RURCAP(J)/1000

where

RWU(J) = rural water use (in MGD) in sub-basin J in the target year

DRPOP(J) = rural population in sub-basin J (in thousands) in the target year

RURCAP(J) = rural water use (gal per capita per day) in sub-basin J in the target year.

4.3.1 Rural Domestic Population

The rural population, DRPOP(J), is computed as the difference between the total population in sub-basin J and the population served by municipalities. The relation is

DRPOP(J) = TPOP(L)*DISTT(J)-POP(L)*DISTP(J)

where

TPOP(L) = the total population (in thousands) in river basin L in the target year

DISTT(J) = proportion of the total population in river basin L that is located in sub-basin J

and POP and DISTP have been defined in the municipal water section.

4.3.2 Required Input Data for Rural Domestic Water Calculations

Required input data for rural domestic water calculations are the vectors RURCAP, DISTT and TPOP.

The subroutine checks DRPOP(J) to see that it is not negative. If it is, an error message is printed out.

4.4. Gross Water Use Calculations

Gross water use is computed in subroutine GROSSW on the basis of information on municipal and rural withdrawals and industrial economic activity. The water required by the industrial activity is computed on the basis of technological water coefficients which vary from sector to sector, from sub-basin to sub-basin, and with type of water use (fresh water, waste water, brackish water, and consumptive use).

4.4.1 Water Requirements of the Industrial Sectors

The equations for gross sectoral water use in sectors I = 1,NSEC are, for fresh water,

```
RWR(I,J,1) = WCOEF1(I,J)*SBGOV(I,J)/365.
```

for brackish water,

```
RWR(I,J,2) = WCOEF2(I,J)*SBGOV(I,J)/365.
```

for waste water,

```
RWR(I,J,3) = WCOEF3(I,J)*SBGOV(I,J)/365.
```

and, consumptive use,

```
RWR(I,J,4) = WCOEF4(I,J)*SBGOV(I.J)/365.
```

where

RWR(I,J,K) = gross water use (in MGD) in sector I of sub-basin J in the target year.

K = 1 denotes fresh water use
K = 2 denotes waste water use
K = 3 denotes brackish water use
K = 4 denotes consumptive use

WCOEFK(I,J) = water required (gallons) to produce one $ of gross output in sector I in sub-basin J in the target year
K = 1 denotes fresh water
K = 2 denotes waste water
K = 3 denotes brackish water
K = 4 denotes consumptive use

I = sector index which runs from 1 to NSEC, the number of industrial sectors.

SBGOV(I,J) = gross output (in $ millions) for sector I in sub-basin J in the target year (This is computed by subroutine INDACT)

Municipal and Rural Sectors

After the industrial water requirements are computed, the RWR array is augmented to include the municipal water use in sector NSECA = NSEC+1 and the rural domestic use in sector NSECB = NSEC+2. The equations used are

RWR(NSECA,J,K) = MWU(J)*MWUF(J,K)

RWR(NSECB,J,K) = RWU(J)*RWUF(J,K)

where

MWUF(J,1) = proportion of total municipal withdrawal that is fresh water in the target year

MWUF(J,2) = proportion of total municipal withdrawal that is waste water in the target year

MWUF(J,3) = proportion of total municipal withdrawal that is brackish water in the target year

MWUF(J,4) = proportion of total municipal withdrawal that is consumed in the target year.

RWUF(J,1) = proportion of rural domestic use that is fresh water in the target year

RWUF(J,2) = proportion of rural domestic use that is waste water in the target year

RWUF(J,3) = proportion of rural domestic use that is brackish water in the target year

RWUF(J,4) = proportion of rural domestic use that is consumed in the target year

4.4.2 Information from Department of Agriculture Studies

At this point, data from Department of Agriculture water studies may be used to modify the gross water use estimates for the agricultural industrial sectors and the rural domestic use sector. This particular procedure for incorporating information for Department of Agriculture studies in the model was selected because the technological water coefficients for the agricultural sectors are possibly not as reliable as the coefficients for the other sectors. Accordingly, whenever the gross water use in an agricultural sector is modified on the basis of DA studies, the imputed technological water coefficients for that sector are printed out.

The user has 4 options available to him for making use of the DA water information, and he may select the option he prefers by setting the variable IFLAG equal to 0, 1, 2, or 3. The options are

IFLAG = 0, the DA water use estimates are not substituted

= 1, the DA water use estimates are substituted if the DA estimates exceed the input-output estimate

= 2, the DA water use estimates are substitutes if the DA estimates are smaller than the input-output estimates

=3, the DA water use estimates are substituted for the input-output estimates.

The following information is required from the DA study, if IFLAG>0. (If IFLAG = 0, these data are not required.)

AGWS(J) = agricultural water supply (in MGD) in sub-basin J in the target year

AGIR(J) = crop irrigation (MGD) in sub-basin J in the target year

NAGIR(J) = other irrigation (MGD) in sub-basin J in the target year.

These data are applied by subroutine CONST according to the option given by IFLAG.

The constraint AGWS(J) may be applied to

$$SAGWS1+SAGWSR = \sum_{K=1}^{3} RWR(IAGR1J,K)+\sum_{K=1}^{3} RWR(NSECB,J,K)$$

where

IAGR1 = index of the agricultural sector for livestock and other non-irrigation agricultural activity (in the NAR study IAGR1 = 1 and this is set as a "default" value should the user not specify a different value)

$$SAGWS1 = \sum_{K=1}^{3} RWR(IAGR1,J,K)$$

$$SAGWSR = \sum_{K=1}^{3} RWR(NSECB,J,K)$$

If the constraint controls, new values of RWR are computed by the FORTRAN statements

$$C = \frac{AGWS(J)}{SAGWS1+SAGWSR}$$

RWR(IAGR1,J,K) = C*RWR(IAGR1,J,K)

RWR(NSECB,J,K) = C*RWR(NSECB,J,K)

for K = 1,4. Should the constraint be substituted, the implied technological waste coefficientsnare computed according to

WCOEFI(K) = (RWR(IAGR1,J,K)/SBGOV(IAGR1,J,K))*365

PCOEF(K) = (RWR(NSECB,J,K)/DRPOP(J))*1000.

for K = 1,4 where

WCOEFI(K) = the implied technological water coefficient (gal/$output) for water use K. Because these implied coefficients are not stored for subsequent use (but printed out and then destroyed), they are not subscripted by I or J.

The constraint AGIR(J) may be applied to

$$SAGIR = \sum_{K=1}^{3} RWR(IAGR2,J,K)$$

where

IAGR2 = index of the agricultural sector for crop irrigation (in the NAR study IAGR2 = 2 and this is set as a "default" value should the used not specify a different value)

If the constraint controls, new values of RWR are computed by the Fortran statements

```
C = AGIR(J)/SAGIR
RWR(IAGR2,J,K) = C*RWR(IAGR2,J,K);K=1.3
RWR(IAGR2,J,4) = AGIR(J)
```

Should the constraint be substituted, the implied technological water coefficients are computed according to

```
WCOEFI(K) = (RWR(IAGR2,J,K)/SBGOV(IAGR2,J))*365.
```

The constraint NAGIR(J) may be applied to

$$SNAGIR = \sum_{K=1}^{3} RWR(INAG37,J,K)$$

where

INAG37 = index of the sector where irrigation accounted for in the DA study, other than crop irrigation, occurs (in the NAR study INAG37 = 37 and this is set as a "default" value should the user not specify a different value)

If the constraint controls, new values of RWR are computed by the FORTRAN statements

```
C = NAGIR(J)/SNAGIR
RWR(INAG37,J,K) = C*RWR(INAG37,J,K);K=1,3
RWR(INAG37,J,4) = NAGIR(J)
```

Should the constraint be substituted, the implied technological water coeffieients are computed according to

```
WCOEFI(K) = (RWR(INAG37,J,K)/SBGOV(INAG37,J))*365
```

4.4.2B OPTION FOR THE POWER COOLING SECTOR

Data from the Federal Power Commission for gross water use in the power cooling sector may be modified by utilizing one of the four options made available through "Subroutine Power" of the demand model.

The options are:

IPWR = 0, the FPC water use estimates are substituted as they appear in the WCOEF's.

IPWR = 1, new input estimates are substituted if they are greater than the FPC estimates.

IPWR = 2, new input estimates are substituted if they are smaller than the FPC estimates.

IPWR = 3, new input estimates are always substituted for existing FPC estimates.

The following information is needed if IPWR>0. (If IPWR = 0, these data are not required.)

QPWR(J,K) = new input estimates of power cooling gross water use in sub-basin (J) for water use (K) in MGD.

If the new constraint controls, new values of RWR are computed by the Fortran statement:

RWR(IPOW30,J,K) = QPWR(J,K)

Should the constraint be substituted, the implied technological water coefficients are computed according to:

WCOEFI(K) = QPWR(J,K)/SBGOV(IPOW30,J) * 365.

where:

WCOEFI(K) = the implied technological water coefficient (gal/$output) for water use K.

IPOW30 = index of power cooling sector (in the NAR study IPOW30 = 30 and this is set as a "default" value should the user not specify a different value.)

4.4.3 Expansion of the RWR Array to Account for Publicly Supplied Industrial Water

After the Department of Agriculture water study information has been incorporated, adjustments in the RWR array

are made to account for the fact that some of the industrial water is publicly supplied. Some of the industrial sectors receive all of the water from municipalities, other sectors are completely self-supplied and some receive part of their water from municipalities and self-supply the other part. At this point, then, the total gross use implied by the sum of RWR over all sub-basins for any I and K=1 or K=4 is actually greater than the true total because some of the water use is counted twice.

To account for the publicly supplied industrial water, adjustments are made to the RWR array. When the adjustments are completed, the RWR array has been expanded and has elements RWR(I,J,KK) where I=1,NSECB, J=1,NSUB andKK=1.6. The index KK denotes type of use as follows.

KK = 1 denotes total gross use by sector I in sub-basin J in the target year

KK = 2 denotes self-supplied fresh water use

KK = 3 denotes publicly supplied fresh water use

KK = 4 denotes waste water use

KK = 5 denotes brackish water use

KK = 6 denotes consumptive use

The RWR array is expanded in the following way. First, for sectors I=1,NSEC, the original values of RWR for K=4 are moved to KK=6; RWR for K=3 are moved to KK=5; and RWR for K=2 are moved to KK=4. This is done for all sub-basins. Then, the publicly supplied water is computed by

RWR(I,J,KK) = RWR(I,J,K)*MSAF(I,J)

where KK=3, K=1 and

MSAF(I,J) = proportion of industrial water use in sector I, sub-basin J that is publicly supplied.

The self-supplied water is computed by

$$RWR(I,J,KK) = RWR(I,J,K)*(1-MSAF(I,J))$$

where KK=2 and K=1. Finally, the total gross withdrawal is computed by

$$RWR(I,J,1) = \sum_{KK=2}^{5} RWR(I,J,KK)$$

When the expansion of RWR for sectors I=1,NSEC is complete, the array may be expanded for the municipal and rural domestic sectors NSECA and NSECB.

Expanding sector NSECA first, requires several steps. The total publicly supplied industrial fresh water is computed according to

$$PSW(J) = \sum_{I=1}^{NSEC} RWR(I,J,3)$$

and the publicly supplied industrial consumptive use is computed according to

$$PSCON(J) = \sum_{I=1}^{NSEC} \frac{RWR(I,J,3)}{RWR(I,J,1)} RWR(I,J,6)$$

Then, the RWR values for sector NSECA are computed according to

$$RWR(NSECA,J,KK) = RWR(NSECA,J,K)-PSCON(J)$$

where KK=6 and K=4

$$RWR(NSECA,J,KK) = RWR(NSECA,J,K)$$

where KK=5 and K=3, and KK=4 and K=2

$$RWR(NSECA,J,KK) = 0$$

where KK=0

$$RWR(NSECA,J,KK) = RWR(NSECA,J,K)-PSW(J)$$

where KK=2 and K=1

$$RWR(NSECA,J,1) = \sum_{KK=2}^{5} RWR(NSECA,J,KK)$$

The resulting value of RWR for sector NSECA may be interpreted as the domestic part of the municipal withdrawal since all of the publicly supplied water for any economic activity has now been abstracted. Associated with the domestic use, which now has been computed, are domestic water coefficients. The implied domestic fresh water coefficient (gal/capita/day) is computed according to the quantity

$$(RWR(NSECA,J,2)/DPOP(J))*1000$$

If the implied fresh water coefficient is less than 49 gal/capita/day (gpcd), the value of RWR(NSECA,J,2) is increased so that the implied per capita fresh water use is equal to 49 gpcd. This increase in RWR(NSECA,J,2) when it occurs is computed before the total use RWR(NSEAC,J,1) is computed; thus RWR(NSECA,J,1) is always estimated so that the per capita daily use is not less than 49 gpcd.

If the implied fresh water coefficient is less than 50 gal/capita/day, a message is printed out.

The implied domestic consumptive use coefficient (gal/capita/day) is computed according to the quantity

(RWR(NSECB,J,6)/DPOP(J))*1000

If the implied fresh water consumptive use, RWR(NSECA,J,6), is less than 5 per cent of the total use, RWR(NSECA,J,1), the value of RWR(NSECA,J,6) is set equal to 5 per cent of RWR(NSECA,J,1).

Expansion of RWR for the rural domestic sector, NSECB, is done according to:

RWR(NSECB,J,KK) = RWR(NSECB,J,K)

for KK=6 and K=4; KK=5 and K=3; and KK=4 and K=2;

$$RWR(NSECB,J,KK) = 0. \quad \text{for } KK=3 \text{ and}$$

$$RWR(NSECB,J,KK) = RWR(NSECB,J,K) \quad \text{for } KK=2 \text{ and } K=1.$$

$$RWR(NSECB,J,1) = \sum_{KK=2}^{5} RWR(NSECB,J,KK)$$

4.4.4 Comparison of Consumptive Use and Total Use

The final step of the gross water calculations is to check to see if the consumptive use is less than the total gross use in each sector of each sub-basin. If not, a message is printed out.

4.4.5 Required Input Data for Gross Water Use Calculations

The required input information for the grosswater calculations consists of the arrays WCOEF1, WCOEF2, WCOEF3, WCOEF4, MWUF, RWUF, and MSAF and scalor IFLAG. If IFLAG>0 the vectors AGWS, AGIR, and NAGIR as well as the scalors IAGR1, IAGR2 and INAG37 are required. Default options are provided for IAGR1, IAGR2 and INAG37 so values do not need to be given for these if the default option values are acceptable. The default values are

IAGR1 = 1

IAGR2 = 2

INAG37 = 37

4. 5. Net Water Demands

Gross water demands in a sub-basin may be supplied, in part, by recycling or re-use within the sub-basin. Therefore, the net demand which must be supplied in a sub-basin, perceived externally, is possibly less than the gross water demand. The net water demand rather than the gross demand, is required to determine the water supply needs of each sub-basin. In addition, it is necessary to specify the water needs that must be supplied from ground water.

The transformation from gross water demands to net water demands involves the following steps: (i) a set of 9 "water use categories" is defined, (ii) water requirements of the NSECB different sectors are assigned to one or more of these categories, (iii) the fresh water needs in 3 of the water use categories may be supplied by recycling within the sub-basin so this is accounted for, (iv) the net water demands for a given sub-basin are presented as a tableau in which the columns correspond to water-use categories and the rows to type of use (i.e. fresh, waste, brackish or consumptive).

The 9 water use categories are

Category	Explanation
1	Municipal and Industrial (PubliclySupplied)
2	Commercial and Industrial (Self Supplied)
3	Agricultural Supply (Unassigned)
4	Agricultural Supply (Ground Water)

Category	Explanation
5	Irrigation (Unassigned)
6	Irrigation (Ground Water)
7	Power Cooling
8	Total Unassigned Without Cooling
9	Total Assigned Ground Water

The new water demands are stored in the array NWDM(I,J,K) where I denotes water use category, J denotes sub-basin and K denotes type of use. This array is generated by subroutine NETW.

4.5.1 Correspondence Between Net Water Demands and Gross Water Demands

The following mathematical relationships are used to compute the net water demands.

4.5.1.1 Water-Use category 1: Municipal and Industrial (Publicly Supplied)

$$(NWDM(1,J,K) = (RWR(NSECA,J,KK)+PSW(J)/SAMIL(J)$$

for K=1 and KK=2. (Note, the quantity RWR(NSECA,J,KK)+PSW(J) is the same as MWU(J)).

$$NWDM(1,J,K) = RWR(NSECA,J,KK)$$

for K=2 and KK=4 and for K=3 and KK=5

$$NWDM(1,J,K) = RWR(NSECA,J,KK)+PSCON(J)$$

for K=4 and KK=6

4.5.1.2 Water Use Category 2: Commercial and Industrial (Self Supplied)

$$NWDM(2,J,K) = (\sum_{I \in S} RWR(I,J,KK))/SAIL(J)$$

for K=1 and KK=2 where 5 is the set of all sector indicies from 1 to NSEC except for IAGR1, IAGR2, IPOW30 and INAG37.

$$NWDM(2,J,K) = \sum_{I \in S} RWR(I,J,KK)$$

for K=2 and KK=4 and for K=3 and KK=5

$$NWDM\ (2,J,K) = SUM - PICON\ (J)$$

for K=4, KK = 6, where

$$SUM = \sum_{\substack{I=3-29 \\ I=31-36}} RWR\ (I,J,KK) \text{ and}$$

$$PI\ CON\ (J) = \sum_{\substack{I=3-29 \\ I=31-36}} \left\{ \left[\frac{RWR(I,J,3)}{RWR(I,J,1)} \right] * RWR(I,J,6) \right\}$$

4.5.1.3 <u>Water Use Category 3: Agricultural Supply (Unassigned)</u>

$$NWDM(3,J,K) = (RWR(IAGR1,J,KK)+RWR(NSECB,J,KK))*AWSSF(J)$$

for K=1,2,3,4 and KK=2,4,5,6 respectively.

4.5.1.4 <u>Water Use Category 4: Agricultural Supply (Ground Water)</u>

$$NWDM(4,J,K) = (RWR(IAGR1,J,KK)+RWR(NSECB,J,KK))* (1. -AWSSF(J))$$

for K=1,2,3,4 and KK=2,4,5,6 respectively

4.5.1.5 <u>Water Use Category 5: Irrigation (Unassigned)</u>

$$LL = KK$$

$$IF(KK.EQ.2)\ LL = 3$$

$$NWDM(5,J,K) = RWR(IAGR2,J,KK)*CROPIR(J)+RWR(INAG37,J,LL)* OTIR(J)$$

for K=1,2,3, and KK=2,4,5,6 respectively, and for K=4

$$NWDM\ (5,J,K)= RWR\ (IAGR2,J,KK) * CROPIR\ (J) +$$

$$OTIR(J)*\left[RWR(INAG37,J,KK) - \frac{RWR(INAG37,J,3)*RWR(INAG37,J,6)}{RWR(INAG37,J,1)} \right]$$

4.5.1.6 Water Use Category 6: Irrigation (Ground Water)

$$NWDM(6,J,K) = RWR(IAGR2,J,KK)*(1-CROPIR(J)) + RWR(INAG37,J,KK)*(1-OTIR(J))$$

for K=1,2,3, and KK=2,4,5,6 respectively, and for K=4

$$NWDM(6,J,K) = RWR(IAGR\ 2\ J,KK)*(1-CROPIR(J)) + (1-OTIR(J))*\left[RWR(INAG37,J,KK) - \frac{(RWR(INAG37,J,3)*RWR(INAG37,J,6)}{RWR\ (INAG37,\ J,1\ )}\right]$$

4.5.1.7 Water Use Category 7: Power Cooling

$$NWDM(7,J,K) = RWR(IPOW30,J,KK)/SAPCL(J)$$

for K=1 and KK=2

$$NWDM(7,J,K) = RWR(IPOW30,J,KK)$$

for K=2,3,4 and KK=4,5,6 respectively

4.5.1.8 Water Use Category 8: Total Unassigned Without Cooling

$$NWDM(8,J,K) = \sum_{I=1}^{3} NWDM(I,J,K)+NWDM(5,J,K)$$

for K=1,2,3,4

4.5.1.9 Water Use Category 9: Total Assigned Ground Water

$$NWDM(9,J,K) = NWDM(4,J,K)+NWDM(6,J,K)$$

for K=1,2,3,4

4.5.2 Input Data Required for New Water Demand Calculations

Required data input to the model for net water demand calculations consists of the vectors SAMIL, SAIL, SAPCL, AWSSF, CROPIR AND OTIR, and the scalers IAGR1, IAGR2, and IPOW30.

DEPARTMENT OF THE ARMY
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IN REPLY REFER TO

19 December 1969

PLAN FORMULATION MEMORANDUM 13
TO MEMBERS OF THE AD HOC WORK GROUP ON PLAN FORMULATION
NORTH ATLANTIC REGIONAL WATER RESOURCES STUDY

In accordance with procedures discussed at the Coordinating Committee meeting in Burlington, Vermont, in June 1969, the NAR staff, in consultation with some work group members, has been engaged in the development of demand and supply models for use in the second phase of plan formulation. Through the use of the demand model, and a large computer, it will be possible to readily develop flow requirement patterns for the various NAR objectives, and to rapidly test the effect of variations in economic assumptions or other changes in terms of water withdrawal and consumption requirements. With the supply model, potential surface and ground water developments will be compared with net demands with the objective of minimizing the costs of supply.

In the development of the models, it became apparent that there would be some major disadvantages in working with the 21 NAR basins. Because of the large size of these basins and the localized nature of many of the needs, the designation of smaller planning units is necessary in most cases to assure that the comparisons of net needs with available supplies will lead to the development of meaningful plans. Accordingly, the 21 NAR basins have been sub-divided into 50 plan formulation working areas, principally on the basis of first round information on requirements, devices, and supplies and area size. The following three inclosures describe these tentative plan formulation sub-areas:

1. A listing with a brief description and an estimate of the land and water area of each of the 50 sub-areas.

2. A list of counties in each of the sub-areas, including a percentage split in those cases where it appears that an overlap between county and hydrologic boundaries would be significant in plan formulation.

3. A map showing the boundaries of the 50 sub-areas in relation to the NAR sub-regions and basins.

It is requested that work group members review their first round data and methodologies in relation to the purpose of the second phase of plan formulation which is to develop realistic requirement patterns and to disclose the implications of varying the basic data and assumptions involved. It will be to the advantage of each member and facilitate the work of the group if (1) the best planning material currently available is utilized, and (2) the data are presented on the basis of the 50 subareas. First priority will be given to preparation of data used to describe flow requirements such as presented in Tables 1-6 of the first-round report.

At the next meeting of the work group on 8 January 1969, members should be prepared to discuss their methodologies and the preparation or adaptation of their data.as outlined above.

3 Incl
as

HARRY E. SCHWARZ
Chairman
Plan Formulation Work Group

50 SUB-AREAS FOR PLAN FORMULATION

Sub-Area	Description	Approximate Land & Water Area In NAR - Sq. Mi.
1a	St. John - Main stem	4,330
1b	Aroostook R. & remainder St. John	3,029
2	Penobscot R. Basin	8,525
3	Kennebec R. Basin	5,870
4a	Androscoggin R. above Gorham, Me.	1,363
4b	Androscoggin R. - remainder	2,087
5a	St. Croix R. Basin	1,010
5b	Maine Coastal region - remainder	5,225
6a	Presumpscot R. & Coastal region	998
6b	Saco R. Basin	1,697
6c	Piscataqua R. & Coastal region	1,513
7a	Merrimack R. above Goffs Falls, N.H.	3,092
7b	Merrimack R. - remainder	1,958
8a	Conn. R. above Dalton, N.H.	1,400
8b	Conn. R. above Vernon, Vt. (local area)	4,752
8c	Conn. R. above Thompsonville, Conn. (local area)	3,395
8d	Conn. R. - remainder	1,589
9a	Mass. Coastal area	2,335
9b	Narragansett Bay Drainage, Pawcatuck R.	2,241
10a	Thames R. & Coastal region	1,710
10b	Housatonic R. & Coastal region	2,845
11a	Lake Champlain drainage	8,294
11b	St. Lawrence R. drainage	3,606
12a	Mohawk R. above Little Falls, N.Y.	1,348

Sub-Area	Description	Approximate Land & Water Area In NAR - Sq. Mi.
12b	Hudson R. above Albany, N.Y. (local area)	7,212
12c	Hudson R. basin - remainder	4,805
13a	Nassau & Suffolk Co.	1,397
13b	New York City Area	504
14	Passaic R., Raritan R. & No. Jersey Streams	2,376
15a	Delaware R. above Montague, N.J.	3,480
15b	Delaware R. above Trenton, N.J. vic. (local area)	3,533
15c	Schuylkill R. above Pottstown, Pa.	1,147
15d	Delaware R. basin - remainder	4,605
16a	Monmouth Co. Streams	372
16b	Remainder of New Jersey Coastal area	2,021
17a	Susquehanna R. above Towanda, Pa.	7,797
17b	W. Br. Susquehanna R. above Williamsport, Pa.	5,682
17c	Juniata R. above Newport, Pa.	3,354
17d	Susquehanna R. above Harrisburg, Pa. (local area)	7,267
17e	Susquehanna R. basin - remainder	3,410
18a	Patuxent R. & West Shore Chesapeake Bay	2,705
18b	East Shore Ches. Bay & remainder Delmarva Pen.	5,440
19a	Potomac R. above Hancock, Va.	4,073
19b	Shenandoah R. above Millville, Va.	3,040
19c	Potomac R. - remainder	7,557
20a	Rappahannock R. basin	2,700
20b	York R. basin	3,300
21a	James R. above Scottsville, Va.	4,571
21b	James R. above Hopewell, Va. (local area)	4,949
21c	James R. basin - remainder	1,080

NORTH ATLANTIC REGIONAL WATER RESOURCES STUDY
SUB-DIVISION BY COUNTIES

MAJOR SUB-REGION	RIVER BASIN OR AREA	SUB-AREA	COUNTY	STATE
A	1	1a	25% Aroostook	Maine
		1b	75% Aroostook	Maine
	2	2	Penobscot	Maine
			Piscataquis	Maine
	3	3	Franklin	Maine
			Kennebec	Maine
			Somerset	Maine
	4	4a	75% Coos	N. H.
		4b	Androscoggin	Maine
			Oxford	Maine
	5	5a	30% Washington	Maine
		5b	Hancock	Maine
			Knox	Maine
			Lincoln	Maine
			Sagadahoc	Maine
			Waldo	Maine
			70% Washington	Maine
B	6	6a	Cumberland	Maine
		6b	60% York	Maine
			Carroll	N. H.
		6c	40% York	Maine
			Rockingham	N. H.
			Strafford	N. H.
	7	7a	Belknap	N. H.
			65% Hillsboro	N. H.
			Merrimack	N. H.
		7b	35% Hillsboro	N. H.
			35% Essex	Mass.
			15% Middlesex	Mass.
			35% Worcester	Mass.

MAJOR SUB-REGION	RIVER BASIN OR AREA	SUB-AREA	COUNTY	STATE
B (Cont'd)	8	8a	25% Coos	N. H.
			Essex	Vermont
		8b	Grafton	N. H.
			Sullivan	N. H.
			Caledonia	Vermont
			Orange	Vermont
			Windham	Vermont
			Windsor	Vermont
		8c	Cheshire	N. H.
			Franklin	Mass.
			Hampden	Mass.
			Hampshire	Mass.
		8d	Hartford	Conn.
			Middlesex	Conn.
	9	9a	Barnstable	Mass.
			Dukes	Mass.
			65% Essex	Mass.
			85% Middlesex	Mass.
			Nantucket	Mass.
			Norfolk	Mass.
			20% Plymouth	Mass.
			Suffolk	Mass.
		9b	Bristol	Mass.
			80% Plymouth	Mass.
			65% Worcester	Mass.
			Bristol	R. I.
			Kent	R. I.
			Newport	R. I.
			Providence	R. I.
			Washington	R. I.
	10	10a	New London	Conn.
			Tolland	Conn.
			Windham	Conn.
		10b	Berkshire	Mass.
			Fairfield	Conn.
			Litchfield	Conn.
			New Haven	Conn.

MAJOR SUB-REGION	RIVER BASIN OR AREA	SUB-AREA	COUNTY	STATE
C	11	11a	Addison	Vermont
			Chittenden	Vermont
			Franklin	Vermont
			Grand Isle	Vermont
			Lamoille	Vermont
			Orleans	Vermont
			Rutland	Vermont
			Washington	Vermont
			Clinton	New York
			Essex	New York
		11b	Franklin	New York
			St. Lawrence	New York
	12	12a	Herkimer	New York
			Oneida	New York
		12b	Albany	New York
			Fulton	New York
			Hamilton	New York
			Montgomery	New York
			Rensselaer	New York
			Saratoga	New York
			Schenectady	New York
			Schoharie	New York
			Warren	New York
			Washington	New York
			Bennington	Vermont
		12c	Columbia	New York
			Dutchess	New York
			Greene	New York
			Orange	New York
			Putnam	New York
			Rockland	New York
			Ulster	New York
	13	13a	Nassau	New York
			Suffolk	New York
		13b	Bronx	New York
			Kings	New York
			New York	New York
			Queens	New York
			Richmond	New York
			Westchester	New York

MAJOR SUB-REGION	RIVER BASIN OR AREA	SUB-AREA	COUNTY	STATE
D	14	14	Bergen	New Jersey
			Essex	New Jersey
			Hudson	New Jersey
			Hunterdon	New Jersey
			Middlesex	New Jersey
			Morris	New Jersey
			Passaic	New Jersey
			Somerset	New Jersey
			Union	New Jersey
	15	15a	Delaware	New York
			Sullivan	New York
			Pike	Pennsylvania
			Wayne	Pennsylvania
		15b	Mercer	New Jersey
			Sussex	New Jersey
			Warren	New Jersey
			Bucks	Pennsylvania
			Carbon	Pennsylvania
			Lehigh	Pennsylvania
			Monroe	Pennsylvania
			Northampton	Pennsylvania
		15c	Berks	Pennsylvania
			Schuylkill	Pennsylvania
		15d	Burlington	New Jersey
			Camden	New Jersey
			Cumberland	New Jersey
			Gloucester	New Jersey
			Salem	New Jersey
			Chester	Pennsylvania
			Delaware	Pennsylvania
			Montgomery	Pennsylvania
			Philadelphia	Pennsylvania
			Kent	Delaware
			New Castle	Delaware
	16	16a	Monmouth	New Jersey
		16b	Atlantic	New Jersey
			Cape May	New Jersey
			Ocean	New Jersey

MAJOR SUB-REGION	RIVER BASIN OR AREA	SUB-AREA	COUNTY	STATE
E	17	17a	Broome	New York
			Chemung	New York
			Chenango	New York
			Cortland	New York
			Madison	New York
			Otsego	New York
			Steuben	New York
			Tioga	New York
			75% Bradford	Pennsylvania
			50% Susquehanna	Pennsylvania
			50% Tioga	Pennsylvania
		17b	Cameron	Pennsylvania
			Centre	Pennsylvania
			Clearfield	Pennsylvania
			Clinton	Pennsylvania
			Lycoming	Pennsylvania
			Potter	Pennsylvania
			50% Tioga	Pennsylvania
		17c	Bedford	Pennsylvania
			Blair	Pennsylvania
			Huntingdon	Pennsylvania
			Juniata	Pennsylvania
			Mifflin	Pennsylvania
		17d	25% Bradford	Pennsylvania
			Columbia	Pennsylvania
			Cumberland	Pennsylvania
			70% Dauphin	Pennsylvania
			Lackawanna	Pennsylvania
			Luzerne	Pennsylvania
			Montour	Pennsylvania
			Northumberland	Pennsylvania
			Perry	Pennsylvania
			Snyder	Pennsylvania
			Sullivan	Pennsylvania
			50% Susquehanna	Pennsylvania
			Union	Pennsylvania
			Wyoming	Pennsylvania
		17e	30% Dauphin	Pennsylvania
			Lancaster	Pennsylvania
			Lebanon	Pennsylvania
			York	Pennsylvania

MAJOR SUB-REGION	RIVER BASIN OR AREA	SUB-AREA	COUNTY	STATE
E (Cont'd)	18	18a	Anne Arundel	Maryland
			Baltimore	Maryland
			Baltimore City	Maryland
			Calvert	Maryland
			Carroll	Maryland
			Hartford	Maryland
			Howard	Maryland
		18b	Sussex	Delaware
			Caroline	Maryland
			Cecil	Maryland
			Dorchester	Maryland
			Kent	Maryland
			Queens Annes	Maryland
			Somerset	Maryland
			Talbot	Maryland
			Wicomico	Maryland
			Worcester	Maryland
			Accomac	Virginia
			Northhampton	Virginia
F	19	19a	Allegany	Maryland
			Garrett	Maryland
			Hampshire	W. Virginia
			Hardy	W. Virginia
			Mineral	W. Virginia
			50% Morgan	W. Virginia
			Pendleton	W. Virginia
		19b	50% Jefferson	W. Virginia
			Augusta	Virginia
			Clarke	Virginia
			*Harrisburg	Virginia
			Page	Virginia
			Rockingham	Virginia
			Shenandoah	Virginia
			*Staunton	Virginia
			Warren	Virginia
			*Waynesboro	Virginia
		19c	Adams	Pennsylvania
			Franklin	Pennsylvania
			Fulton	Pennsylvania
			Charles	Maryland
			Frederick	Maryland
			Montgomery	Maryland
			Prince George	Maryland
			St. Marys	Maryland
			Washington	Maryland

* Independent Cities

MAJOR SUB-REGION	RIVER BASIN OR AREA	SUB-AREA	COUNTY	STATE
F (Cont'd)	19 (Cont'd)	19c (Cont'd)	Berkley	W. Virginia
			Grant	W. Virginia
			50% Jefferson	W. Virginia
			50% Morgan	W. Virginia
			*Alexandria	Virginia
			Arlington	Virginia
			Fairfax	Virginia
			*Falls Church	Virginia
			Fauquier	Virginia
			Frederick	Virginia
			King George	Virginia
			Loudon	Virginia
			Prince William	Virginia
			Stafford	Virginia
			Westmoreland	Virginia
			*Winchester	Virginia
			The District	District of Columbia
	20	20a	Culpeper	Virginia
			Essex	Virginia
			*Fredericksburg	Virginia
			Lancaster	Virginia
			Madison	Virginia
			Middlesex	Virginia
			Northumberland	Virginia
			50% Orange	Virginia
			Rappahannock	Virginia
			Richmond	Virginia
			60% Spotsylvania	Virginia
		20b	Caroline	Virginia
			Gloucester	Virginia
			*Hampton	Virginia
			Hanover	Virginia
			King & Queen	Virginia
			King William	Virginia
			Louisa	Virginia
			Mathews	Virginia
			50% Orange	Virginia
			40% Spotsylvania	Virginia
			York	Virginia

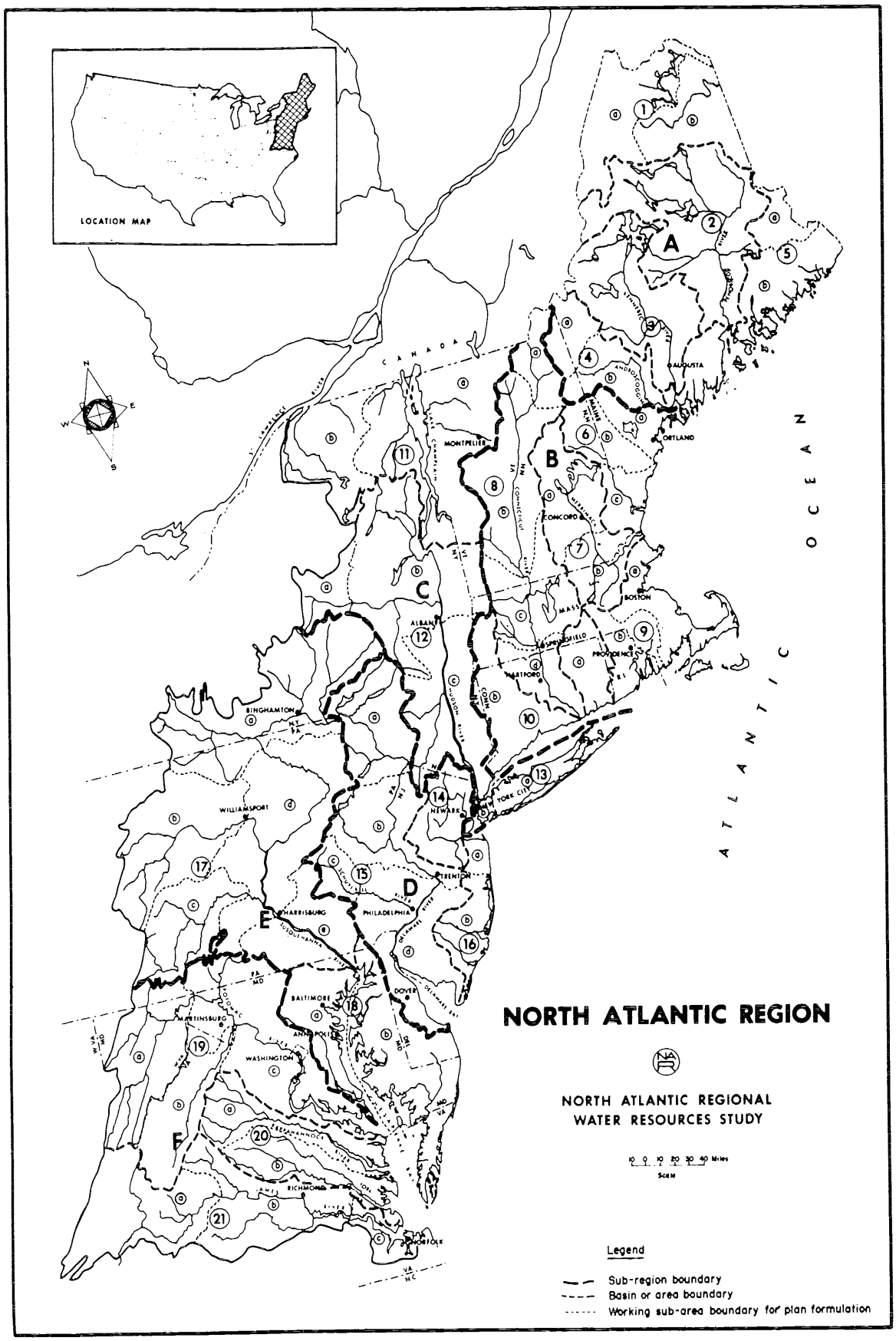
* Independent Cities

MAJOR SUB-REGION	RIVER BASIN OR AREA	SUB-AREA	COUNTY	STATE
F (Cont'd)	21	21a	Alleghany	Virginia
			Amherst	Virginia
			50% Appomattox	Virginia
			Bath	Virginia
			Botetourt	Virginia
			*Buena Vista	Virginia
			*Clifton Forge	Virginia
			*Covington	Virginia
			Craig	Virginia
			Highland	Virginia
			*Lexington	Virginia
			*Lynchburg	Virginia
			Nelson	Virginia
			Rockbridge	Virginia
		21b	Albermarle	Virginia
			Amelia	Virginia
			50% Appomattox	Virginia
			Buckingham	Virginia
			Charles City	Virginia
			*Charlottesville	Virginia
			Chesterfield	Virginia
			*Colonial Heights	Virginia
			Cumberland	Virginia
			Fluvanna	Virginia
			Goochland	Virginia
			Greene	Virginia
			Henrico	Virginia
			*Hopewell	Virginia
			50% James City	Virginia
			New Kent	Virginia
			Nottoway	Virginia
			*Petersburg	Virginia
			Powhatan	Virginia
			Prince Edward	Virginia
			Prince George	Virginia
			*Richmond	Virginia
		21c	*Chesapeake	Virginia
			Isle of Wight	Virginia
			50% James City	Virginia
			*Newport News	Virginia
			*Norfolk	Virginia
			*Portsmouth	Virginia

* Independent Cities

MAJOR SUB-REGION	RIVER BASIN OR AREA	SUB-AREA	COUNTY	STATE
F (Cont'd)	21 (Cont'd)	21c (Cont'd)	*Suffolk	Virginia
			Surry	Virginia
			*Virginia Beach	Virginia
			*Williamsburg	Virginia

* Independent Cities


LOCATION MAP
NORTH ATLANTIC REGION
NORTH ATLANTIC REGIONAL
WATER RESOURCES STUDY
Legend
Sub-region boundary
Basin or area boundary
Working sub-area boundary for plan formulation
ATLANTIC OCEAN
CANADA
A
B
C
D
E
F
AUGUSTA
PORTLAND
MONTPELIER
CONCORD
BOSTON
SPRINGFIELD
PROVIDENCE
HARTFORD
ALBANY
BINGHAMTON
WILLIAMSPORT
NEWARK
NEW YORK CITY
TRENTON
HARRISBURG
PHILADELPHIA
DOVER
BALTIMORE
ANNAPOLIS
MARTINSBURG
WASHINGTON
RICHMOND
NORFOLK

DERIVATION OF DEMAND MODEL INPUT DATA

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DERIVATION OF DEMAND MODEL INPUT DATA

INTRODUCTION

The demand model requires large amounts of diverse input data, before it can generate water withdrawal demands. In generating this large data bank, there were two important guidelines. The first of these is consistency, at least within each group of data entries. For example, population served should be calculated by the same procedure for each objective, for each benchmark year and for each basin. The second guideline is that all major assumptions with regard to the calculating procedures should be clearly stated and understood. Use of these guidelines allow for reproducibility of the results and, more importantly, simplifies the use of the entire system for estimating water withdrawal needs.

In generating the input data, several problems were encountered. These included adjusting the data into the proper form for use in the model, and two type of problems associated with using the projections from other sources, which were:

- o understanding the methodology and the assumpions involved, and
- o reconciling the various assumptions behind projections from more than one source.

Projections were necessary for the three benchmark years, 1980, 2000 and 2020, from a very limited number of observations. These projections were done in a manner which utilized as many existing projections as was possible.

Throughout the development of the methodology, an attempt was made to utilize the most consistent and direct as well as soundest procedures.

The base reference period for this analysis is the mid-1960's. Because of limitations on available reference and input data, the base year for these materials varies from 1963 to 1966.

INPUT DATA ITEMS

The initial set of data inputs to the demand model were the simplest, in the sense that they were only single number entries. These Input Data Items are necessary in order to execute the demand model, and include the following:

oB_i = Elasticity of Municipal Withdrawal to Population Changes

- B_2= Elasticity of Municipal Withdrawal to Income Changes
- GNP= Gross National Product
- PGNP= Proportion of GNP Produced in the Region in the target year
- NRB= Number of Areas in the Region
- NSUB= Number of Sub-areas in the Region
- NSEC= Number of Sectors, excluding Municipal and Rural Domestic Sectors
- NSECA= Index of Municipal Sector
- NSECB = Index of the Rural Domestic Sector

There were 21 Areas in the NAR--NRB is 21; there were 50 Sub-areas--NSUB is 50; there were 39 industrial, agricultural, service and extractive industrial sectors--NSEC is 39. NSECA and NSECB are alphanumeric code names for the municipal sector and the rural domestic sector, respectively. They are the 40th and 41st sectors in the sectoral print-outs. The remaining input data items, GNP, PGNP, B_1 and B_2, require a greater degree of explanation.

GNP figures were taken from projections made by the Office of Business Economics. These projections of GNP were based upon six trend values, which are: population trends, trends in labor force size, total employment, private employment, hours worked, and product per man-hour (productivity). Assumptions were necessary regarding these trend values before the level of GNP could be predicted.

The assumption of either a National Efficiency, a Regional Development or an Environmental Quality objective dictated the acceptable range of the six components of GNP, and, as a result, the actual GNP value. For the base year, 1965, GNP was an historical fact presented in Appendix B, Economic Base. Addendum 2, Table B-5 to Appendix B provides the future projections of GNP which were used for each objective and for each of the three bench mark years, 1900, 2000 and 2020.

A similar procedure, with several modifications, was developed and used in calculating the proportion of GNP (PGNP) produced in the Region. The base year proportion is also an historical fact, and is in Appendix B. PGNP requires a knowledges of the projected Gross Regional Product (GRP). However projections of GRP were not available. A proxy variable had to be used. It was assumed that the proportion of Personal Income in the Region to U.S. Personal Income is the same as the proportion of GRP to GNP.

Income information was readily available in the Office of Business Economics projections in Appendix B. The Projections are also available on the basis of objectives and target years. A further assumption made was that PGNP for each bench mark year is the same for

each objective. This is not an unreasonable assumption because whenever the model was shifted to a different objective - Regional Development on Environmental Quality - for the Region we assumed the GNP would also be generated on the basis of this new objective.

A further word about the various objectives, National Efficiency, Environmental Quality and Regional Development, and the assumptions made to arrive at GNP estimates is necessary. The National Efficiency estimate is the middle value estimate. It involves a moderate assumption about the rates of growth of the six GNP determinants, which follow:

- Population: 1.3%
- Population of working age: 1.4%
- Civilian labor force: 58.3%
- Private civilian employment: 2.3%
- Hours worked per year: annual hours will decline to 1749
- Product per man hour: 3.0%

Environmental Quality makes the assumption that the low population rate of growth assumption is the one which would best reflect the overall level of productive activity. The rate of growth of population would then be 1.0 per cent. The Regional Development objective assumes that action will be taken to maximize Regional output. This implies the level of productivity will be that of our high assumption. This rate is 3.2 percent with all other variables assumed to grow at the same rate as the National Efficiency objective.

The remaining two imput data items, B_1 and B_2, were both estimated from the regression equation. B_1 gives the percentage change of municipal withdrawal related to percentage changes in population, (elasticity of municipal withdrawal with respect to population changes), while B_2 relates percentage changes in the municipal demands to percentage changes in income (elasticity of municipal withdrawal to income changes). B_1 and B_2 were estimated for the base year and are assumed constant for the future benchmark years and the various objectives.

Most of the input data items are fixed for this particular construction of the problem, however, as the user's manual points out, the demand model itself possesses a greater flexibility than that. Clearly NRB, NSEC, NSECA, NSECB and NSUB are the fixed dimensions of the Region. The GNP item can be and is altered depending upon the assumptions that have been made concerning the level of economic activity in the Region. PGNP can take any value depending upon the assumptions made. The PGNP value here reflects the OBE projections. B_1 and B_2 are calculated on the basis of the regression equation. Input data items are easily modified or altered.

INPUT DATA BY ROWS OR COLUMNS

The second group of input entries consisted of input vectors. Input vectors are either a single column or row of data. There are 27 input vectors to the demand model, and they can be separated into groups by the type of information contained.

Agricultural Vectors

The first group considered was those input vectors dealing with agricultural water use, including:

- AGIR- Agricultural water use for irrigation in Sub-area (J)
- AGWS- Agricultural water use other than for irrigation in the target year in Sub-area (J)
- AWSSF- Proportion of Agricultural supply unassigned in the target year in Sub-area (J)
- CROPIR- Proportion of agricultural water use for irrigation unassigned in the target year
- NAGIR- Non-agricultural irrigation use in Sub-area (J) in the target year.
- OTIR- Proportion of Non-Agricultural Irrigation in Sub-area (J) unassigned in the target year

AGIR was based on information found in Appendix I, Irrigation, and supplemental data furnished by the Department of Agriculture. Data were available for the 50 Sub-areas. AGIR was calculated as the peak month demand by converting the largest monthly demand (which was given as % of gross seasonal requirement) from acre-feet to an equivalent average low in m.g.d. for a 30-day period.

NAGIR was also calculated on the basis of estimates in Appendix I and a table of supplemental information provided by the Department of Agriculture. Data available for the 50 Sub-areas were similar to the AGIR data. Peak month non-agricultural irrigation withdrawals in MGD'S for the 50 Sub-areas were calculated by the same procedure employed in converting AGIR data.

The OTIR and CROPIR input vectors also derived simultaneously. The CROPIR values were provided for the study by the U.S. Department of Agriculture's Soil Conservation Service (SCS), which provided Agricultural Irrigation Source Factors. These were the percentages of total irrigation figures provided by various supply sources (i.e. ground water). Since the CROPIR vector is concerned with unassigned water use (agricultural demands which may be met by the various sources available using a least cost criteria and not specifically assigned to ground water) the SCS numbers were very useful. Using the fact that all agricultural demands are either assigned or unassigned the development of the CROPIR vector proceeded in this manner:

1- % Assigned in Sub-area (J) = % Unassigned in Sub-area (J)

This was done for all 50 Sub-areas. In connection with OTIR, estimates of demand satisfied by various sources of supply were also developed by the Department of Agriculture. The OTIR vector was developed in the same manner as the CROPIR vector.

The remaining two input vectors in this first grouping, AGWS and AWSSF, were both supplied by the Department of Agriculture. They involved no calculation or manipulation for use as model input.

All of the agricultural input vectors were projected into the future using the same methodology as was developed for the base year. The base year values for CROPIR, and OTIR were used for all benchmark years and objectives.

Population and Income

The next task was the development of the input vectors containing information about population, per capita income and population served. These included:

- BTPOP-Total population in Area (L) in the base year
- TPOP-Total population in Area (L) in the target year
- BPOP-Population in Area (L) that is served by municipal supplies in the base year
- POP-Population in Area (L) that is served by municipal supplies in the target years
- BY-Per capita income in Area (L) in the base year
- Y-Per capita income in Area (L) in the target year

The reference year for population and economic parameters was 1965. Base year total population (BTPOP) was derived from data generated by the Office of Business Economics and contained in Appendix B. The data is listed by water-use regions which were adjusted to coincide with the 21 Areas or basins in the demand model. Since the OBE had total population figures for 1960 and 1980 it was necessary to get an estimate for the 1965 figures. A straight line interpolation was used between the years 1960, 1980 to get a 1965 value for total population in the 21 NAR Areas. The base year population served (BPOP) was derived from an inventory of municipal water supply systems for the northeastern portion of the United States. This inventory was prepared for the Northeastern United States Water Supply (NEWS) Study and was adjusted by county to fit the 21 Areas of the model.

Base year per capita income data are also available in Appendix B. Calculation of base year per capita income (BY) involved certain adjustments. All counties in NAR were grouped in the 23 Water Resource Planning Areas that the OBE used for its base figures and its projections. The percentage of the Water Resource Planning Area's total income found in each county was calculated and the counties were the rearranged into the 21 Areas of the NAR study. The percentage of total WRPA income in each county was applied to the total income of the respective WRPAS that the county was located in and total county incomes were generated and then aggregated for each Area.

There were two shifts in county income which were made subsequent to the initial formulations. The first involved shifts between Areas 7 and 9. Middlesex County was partially shifted out of Area 7, with about 85% shifted into Area 9. Also, two other county populations and total incomes were shifted between NAR 7 and 9. Thirty-five percent of Essex County was shifted from Area 9 to Area 7 and 65% of Worcester was shifted from Area 7 to Area 9.

The second revision involved a shift between NAR Areas 4 and 8. Area 8's total population initially included all of Coos County, N.H. This was felt to be an overstatement since most of the population and industrial activity of that county actually is located in Area 4. A decision was made to shift 75% of Coos County into Area 4. Area 8's income, population and earning figures were reduced accordingly.

The procedure used in adjusting Area income was carried out for adjusting population from the WRPAS to the 21 Areas of the NAR. Per capita income for the base year (BY) was then derived by dividing total population in each of the NAR Areas into total personal income in each of the NAR Areas.

The projections of benchmark year population for the National Efficiency (NE) and Regional Development (RD) objectives were carried out using the same procedure employed in adjusting base year area income. OBE provided projections for 1980, 2000 and 2020 for all the WRPA's. The Regional Plan Association provided population projections by counties for the benchmark years. The adjustment was made to the population and total personal income figures as before except that the Regional Plan Association projections were used as control totals. The adjusted total personal income was then divided by the adjusted total populations for each of the 21 NAR Areas.

The Regional Development per capita income, however, involved an adjustment in total personal income, which was then divided by the adjusted total populations for each of the 21 Areas. The Regional Development objective assumes higher productivity per worker, therefore, higher total personal income would be generated. Personal

incomes were adjusted upward by the ratio of personal income for the NAR under the Regional Development assumption to personal income for the NAR for the National Efficiency assumption. The Regional Development per capita incomes were then the ratio of this adjusted personal income to the population for each of the 21 Areas.

The third objective, Environmental Quality, required more then one adjustment; both population and total personal income had to be altered. The Environmental Quality objective makes the assumption that there will be a slower rate of population growth resulting in a slower growth rate for gross regional income and all the other variables dependent upon the level of output for the Region. Several assumptions had to be made concerning the resulting changes. The population adjustment required the assumption that the ratio of population for the EQ objective for the entire United States to the population for the NE objective for the whole United States is equivalent to the ratio of populations for the Region under the two objectives. This percentage was then applied to the total NAR population for the NE objective. This resulted in the total population for the NAR under the EQ objective which was then distributed to Areas, with the additional assumption that the percentage distribution of total population of the 21 Areas under the NE objective is applicable to the EQ objective as well.

Total income also had to be adjusted because of the EQ assumption of slower population growth and the resulting lower output. The assumption made here was similar to the assumption made for population. It was assumed that the ratio of U.S. personal income for the EQ objective to U.S. personal income for the NE objective is the same as the regional ratio for the two objectives. The percentage was then applied to total income for the NAR under the NE objective to get total income for the EQ objective. This "new" total income figure was then distributed under the same assumption as before: that is, the percentage distribution of personal income among the 21 Areas for NE will be the distribution for EQ as well. Per capita income was then based on the altered population and total personal income.

The final input vector dealing with population (in absolute terms) is the population served by municipal supplies in Area (L) in the target year. The projected values of POP for the years 1980, 2000 and 2020 increase with time because of several important reasons: the anticipated increase in the degree of urbanization in the NAR region; the tremendous amount of surburban expansion that present trends indicate for the future; and the desire by the public for a greater reliability of water supply.

The base populations served, which as previously stated were available from the NEWS study inventory of the Northeast region, were the starting point in developing population served. From these base figures, the percentage that population served was of total

population could be calculated. Estimated growth rates for percent population served (for each Area) were applied to the base percentages. This resulted in projected percentage of total population served by municipal supplies. The percentage was applied to the total population by Area for the NE and RD objectives. The percentage of population served for the EQ objective was assumed to be essentially the same as for NE and RD. The percentage value for each Area should not change because of changes in the level of population (no change in the distribution of population is assumed by the EQ objective).

Distribution Vectors

The third group of input vectors were those dealing with the distribution of total population, population served, and per capita income. These included:

- BDISTP-Proportion of population served by municipal supplies in Area (L) located in Sub-area (J) in the base year
- BDISTY-Ratio of per capita income in Sub-area (J) to per capita income in Area (L) in the base year
- DISTP-Proportion of population served by municipal supplies in Area (L) located in Sub-area (J) in the target year
- DISTT-Proportion of total population in Area (L) located in Sub-area (J) in the target year
- DISTY-Ratio of per capita income in Sub-area (J) to per capita income in Area (L) in the target year.

All of these distributors were calculated for the NE assumptions and were assumed to be applicable to the RD & EQ objectives. The BDISTP and BDISTY are both base year. BDISTP was derived from the Northeastern Water Supply Study (NEWS). Population served by county was available from the inventory carried out by NEWS. The counties were then aggregated into the 50 Sub-areas and the proper ratios formed. BDISTY was calculated on the basis of total income and population figures found in the County and City Data Book by the Department of Commerce. Total income by county and population by county were aggregated to the 50 Sub-areas. Total income was then divided by total population to get per capita income of Sub-area (J). This was then divided by the per capita income for the whole Area as calculated from the County and City data book.

The projections of these variables to form DISTP, DISTT and DISTY for the target years was a slightly more complex problem. The major assumption was that the results for NE target years could be used for EQ and RD benchmark years as well. Since the input vectors

involved are all percentage distributions, it is not unrealistic to make the assumption that productivity increases are uniform throughout the Region (RD assumption) or that a slower rate of growth of population is also uniform throughout the Region (EQ). DISTP was calculated in this manner. Projections for county populations for each benchmark year were available from Regional Plan Association. The counties were then aggregated into the 50 Sub-areas. The Pop-served percentages were then applied to each Sub-area, resulting in Pop-served for each of the 50 Sub-areas. The Sub-areas were than aggregated into the 21 Areas. The ratio of population served in Sub-area (J) to population served in Area (L) was formed for each of the 50 Sub-areas for every benchmark year (1980, 2000, and 2020).

DISTT was obtained in essentially the same way. Total projected population by county - from Regional Plan Association figures - was aggregated into total population by the 50 Sub-areas. The percentage of Area L's population found in Sub-area (J) was then calculated. This is the DISTT vector.

The DISTY vector was calculated using the following procedure. Total population by the 50 Sub-areas was, as previously stated, available. Total income was found in the OBE projections in Appendix B. The WRPA's that OBE used for projections were then adjusted to meet the boundaries of our 21 Areas. Personal income was distributed to the 50 Sub-areas by the percentage of employment in each Sub-area of an Area. The per capita income, personal income divided by total population for each of the 50 Sub-areas, was calculated and DISTY was the ratio of per-capita income in Sub-area (J) to per capita income of river Area (L). This procedure was repeated for all the benchmark years.

Re-Use and Miscellaneous Vectors

The final group of input vectors are those for establishing the re-use factors, base year municipal water use, the regional final demand vector and an index to allocate the Sub-areas to the areas. These included:

- BMWU-Municipal withdrawal in Sub-area (J) in the base year
- INDEX-Index of the Area in which Sub-area (J) is located
- RFDDV-Proportion of GNP produced by sector I in the target year (Regional Final Demand Distribution)
- SAIL-Self-supplied industrial re-use coefficient for Sub-area (J) in the target year.
- SAMIL-Publicly-supplied municipal and industrial re-use coefficient for Sub-area (J) in the target year.

- SAPCL-Power cooling re-use coefficient for Sub-area (J) in the target year.

The BMWU Vector was derived from the inventory carried out by the Northeastern United States Water Supply (NEWS) Study. The municipal water use was available from this inventory by county and county totals were arranged in the same order that the counties fall into the 50 Sub-areas of the NAR study. Proper adjustments were made where county totals had to be split.

INDEX is an input vector which performs the functions its name indicates. It lists the 50 Sub-areas and for each Sub-area the number of the Area that the Sub-area belongs to. The index vector does not change over time nor with the various objectives (RD, EQ, NE).

The RFDDV (Regional Final Demand Distribution Vector) was derived from information found in the Survey of Current Business, an Office of Business Economics publication. The RFDDV vector gives the percentage of the regions' final demand which each of the NAR sectors (agricultural, minerals, industrial and service) contains. The assumption made in deriving this vector was that the national values (RFDDV on the national level) were distributed in the same manner at the regional level. The procedure was very straight forward. The Survey of Current Bsuiness gives total final demand in its report on the National Input-Output table. The input-output sectors were reconciled with the NAR sectors and the total final demand for each sector (according to the NAR breakdown) at the national level was developed. The total final demand for all sectors was then summed up. The RFDDV was the ratio of:

$$\frac{\text{Total Final Demand in Sector I}}{\sum_{I=1}^{39} \text{Total Final Demand in Sector I}}$$

RFDDV was calculated from preliminary information for 1963 and was assumed the same for all future benchmark years and all objectives. It was however, updated when the final 1963 I/O table was published in the Survey of Current Business in November 1969.

There were 3 input arrays for re-use factors. The re-use factors were classified by the water withdrawal type they are applied to and are necessary to convert gross withdrawal to net withdrawal. The first set of re-use factors was the SAIL array. These are industrial re-use coefficients for Sub-area (J) in the target year. The procedure that evolved utilized data which had been generated in the Cornell Study. These withdrawal data were given by 4 digit SIC's by county. The procedure involved dividing the total company fresh intake by the largest withdrawal by 4 digit SIC in each Sub-area. Results were reasonable in most Sub-areas having a single

major river. However, in others the factors were unrealistically high. In these Sub-areas an adjustment was made by reducing the factors in proportion to the number of major watercourses.

The second set of re-use coefficients comprises the SAMIL-publicly-supplied municipal and industrial re-use coefficients for sub-area (J). These were estimated separately on the basis of engineering judgement as to the pattern of development and re-use, if any, associated with this type of water in each of the 50 Sub-areas. The final input array was the SAPCL array, which the power cooling re-use coefficients for each Sub-area (J) in the target year. These were calculated from Federal Power Commission data, which enumerated total fresh water withdrawal by Sub-area for each benchmark year and for each objective, and also the maximum fresh water withdrawal for each Sub-area for each year for each objective. The ratio of total fresh water withdrawal to maximum fresh water withdrawal was then calculated. This was used to develop the re-use factor for all years and all objectives. The SAIL vector was not projected. It was felt that because of the nature of the self-supplied industrial re-use problem, projections could not be developed with confidence, and rather than introduce further uncertainty into the system, the decision was reached to use the 1964 SAIL for all years. The same was decided for SAMIL.

INPUT DATA ARRAYS

The final set of input data is entered into the program in the form of input arrays. These arrays or matrices are the most complex form of entry into the demand model. They include:

- PSTATE (50X3): Proportion of Sub-area (J) located in State (J,K)
- STATE (50X3): 4 Character Alphanumeric abbreviation of the Kth state in which Sub-area (J) is located.
- WCOEF 1 (39X50): Fresh water required (measured in gal.) to produce one dollar ($1) of output in Sector (I) in Sub-area (J) in the target year
- WCOEF 2 (39X50): Waste water required (measured in gal.) to produce one dollar ($1) of output in Sector (I) in Sub-area (J) in the target year
- WCOEF 3 (39X50): Brackish water required (measured in gal.) to produce one dollar ($1) of output in Sector (I) in Sub-area (J) in the target year
- WCOEF 4 (39X50): Consumptive use of (fresh water measured in gal.) in producing one dollar ($1) of output in sector (I) in Sub-area (J) in the target year.

- SSAM (39X50): Proportion of the Regional Economic activity in Sector (I) that takes in Sub-area (J) in the target year.
- RICM (39X39): Regional inverse coefficient matrix, dollars ($) of output from sector (I) required by sector (I+R) in order for Sector (I+R) to add one dollar ($1) increment to GRP in the target year.
- MSAF (39X50): Municipal supply adjustment factor. Proportion of fresh water use in Sector (I), Sub-area (J) that is publicly supplied in the target year.
- MWUF (50X4): Municipal Water Use Factor. Proportion of total municipal withdrawal that is fresh (K=1), waste (K=2), brackish (K=3), and consumptive (K=4), in the target year.
- RWUF (50X4): Rural Water Use Factor. Proportion of total domestic use that is fresh (K=1), waste (K=2), brackish (K=3), and consumptive (K=4), in the target year.

SSAM Array

The SSAM array is used in many of the sub-systems in the model. It is also used in the distribution of WCOEF 1, 2, 3 and 4. The SSAM matrix can be best described by considering groups of sectors whose SSAM entries have been calculated in the same manner. There was, however, some preliminary work that had to be done before the SSAM array could be generated. For each Sub-area a list of counties in that Sub-area was formed. In the case where a county was located in more than one Sub-area, the county was then assigned to the various Sub-areas by the proportion of county total population located in the Sub-area. For example, Aroostook County, Maine was divided between Sub-area's 1a and 1b in this manner: 1a-25%, 1b-75%, by population. This division by population, however, is just an approximation to the actual division desired. The SSAM array is concerned with the distribution of employment by industry in the Sub-areas of the NAR. The division by population makes the assumption that the location of industry and the development of population centers are closely related. This does not seem to be an unreasonable assumption. Therefore the proportion of employment found in the county in various Sub-areas was assigned by the proportion of population of the county found in the various Sub-areas.

The SSAM array was then formed. For each county, employment by 2 digit SIC's was available in County Business Patterns, 1964. For NAR sectors 1-9 and 30-36 this information was removed and aggregated into Sub-areas. Total employment for the NAR is the sum of all these Sub-area employments by sector. Then the individual Sub-area employment by sector was divided by the NAR total for that

sector, giving the SSAM array for this sector and Sub-area:

$$\frac{\text{Employment of industry i in Sub-area j}}{\text{Total employment in industry i.}}$$

The SSAM entries for the industrial sectors 10-29 were generated on the basis of the study done at Cornell University. Data on employment by 4 digit SIC by county was summed to the 2 digit level, aggregated by county into Sub-area and then following the above procedure, into the SSAM values. The SSAM array for 1964 was generated in that manner. Projections for the future benchmark years were than made.

The projections for the sectors 1-7 and 10-29 were again based on information provided by the Cornell study and the Office of Business Economics' projections of future industrial employment. The Office of Business Economics' projections were aggregated to a greater degree than the NAR sectors. The OBE projections are for the 21 Areas for 8 major industrial groups: agriculture + foresty + fisheries, mining, food + kindred products, textile mill products, chemicals + allied products, paper + allied products, petroleum refining and primary metals.

The first step in projecting SSAM is to decide how the employment figures by 21 Areas can be disaggregated into the 50 Sub-areas. It was assumed that the distribution between Sub-areas within an Area would not substantially change over time. This allowed for the projection of the employment data by Sub-area rather than Area, and solved the distributional problem within Areas. The second step involved the correlation of the NAR activity sectors with the 8 aggregated activity projections of the OBE. After careful consideration and investigation into the composition of the NAR activity sectors (SIC Code Book), an assignment of NAR sectors to the 8 aggregated OBE projections was made. For each NAR sector assigned to one of the 8 OBE projected classifications, the following procedure was adopted:

1) For each of the 21 Areas' OBE projections, disaggregate to 50 using the assumption that the internal distribution within an Area doesn't change from the 1964 distribution.
2) Sum up the values for all 50 Sub-areas for each sector.
3) Divide each individual sector by the sum of all of the sectors. This gives the SSAM value for the industry for each Sub-area.

The process was repeated for each benchmark year. The SSAM array was not altered for the various objectives.

Due to a lack of definitive information for the remaining

sectors, it was assumed that base period employment distribution was maintained in the future.

RICM Array

The Regional Inverse Coefficient Matrix (RICM) is the central matrix in the input-output portion of the demand model. This matrix gives the dollar output of industry I necessary for industry J to add one dollar ($) to the gross regional product in the target year.

Regional I/O models cannot be handled in the same way as national I/O models. The difference stems from the disparity in the amount of external trade that exists between regions and nations. Although the pure theory of international trade would suggest that countries would specialize in production and trade to the same extent as regions of comparable size & diversity, political factors (diversity i.e. in case of war) physical distances, real (i.e. quotas) and monetary impediments tend to make nations much more closed, in terms of the extent of trade, than regions of a particular nation. By closed we refer to the fact that the nation will tend to be more self-sufficient and thus rely to a lesser extent on trade for certain goods. Also the regions of a particular nation, will be less closed than the nation itself, due to both the above mentioned impediments to trade for a national state, and the smaller possibility for the diversity necessary for self-sufficiency existing in a region than in the country itself.

These conditions are especially true in a country such as the United States which has resources diverse enough to enable it to be self-sufficient to the extent that imports are only 5.6% of GNP.

The degree of openness that a regional economy exhibits has great relevance in determing the type of methodology that must be used to produce a reliable operational tool. The direct coefficient matrix can be used, with appropriate assumptions, to yield the gross output necessary to support some level of final demand or the level of final demand necessary to bring forth a given gross output. We usually desire information about final demand or gross output to derive some information about the region itself. For instance in our model gross output is projected in order to derive information as to the future industrial water requirements for the NAR. They must refer to the amount required from industry in the region to produce a unit of industry j's output. This is exactly the coefficient derived from the national I/O table for a nation such as the U.S. that is relatively closed. The columns of the direct coefficient matrix derived from such a table will represent the technology being used in the economy. In terms of the inverse coefficient matrix, each coefficient will refer to the gross output produced in the nation necessary to provide some level of final demand no matter where its source.

If we assume either that the national technology holds for the region, or we develop estimates of prevalent technology for the region, our resulting direct coefficient matrix will not yield the same type of results that it yielded for the national economy. The direct coefficients applicable to a regional study must, in order to produce results about activity in the region itself, include information as to the proportion of inputs used to produce a given level of output that is supplied from outside the region in the form of regional imports. For instance, if we desire to derive the change in final demand for a certain industry, we would initially need to obtain the change in regional gross output, in that industry. This could be obtained from the inverse coefficient matrix which is derived from the direct coefficient matrix.

Now let us assume that the industry that interests us does not produce in our region. If this is the case, coefficients that reflect the technology of production will yield erroneous information as to the level of gross output, and thus the level of water requirements in the region. This is clearly contrary to our assumption that the firm does not produce in the region. What is necessary for valid results is direct coefficients that reflect only the change in gross output in the relevant region due to a change in final demand. Thus the regional direct coefficients must be thought of as being composed of two parts; a technological part representing regional technology and a regional, or spatial part representing the interregional supply channels.

The model used in the NAR study is of the type used by Moore and Peterson in their study of Utah's economy. The model focuses on the structure of a particular region and its relationships with all other areas (usually called, the rest of the world). As it is indirect, the regional direct coefficients are derived by adjusting national coefficients to reflect the spatial quality of regional production. In order to apply the procedure, two assumptions must be made, (1) regional technology is identical to national technology, and (2) the region only imports when it has exhausted its own resources. Assumption one is usually made in order to eliminate the immense task of developing actual technological data for a region. It will be close to reality for a large diversified region, that is, the national coefficients can be thought of as a weighted average of regional coefficients and thus a large region would tend to influence national coefficients to a great extent.

Adjustments for regional industrial mix are possible and simple computationally, but difficult to do without access to census data banks. The second assumption enables the model to provide a regional direct coefficient matrix suitable for projections. It implies that the level of exports and imports for a region can be derived given the levels of gross output, intermediate demand, and final demand. With the level of imports by industry and some scheme to

allocate the total amount of imports among the purchasing industries, the regional direct coefficient matrix is easily calculated. To clarify the exposition, a numerical example will be introduced. We start with a national flow table, values for national gross output, regional gross output, and regional final demand. Regional gross output and regional final demand can be estimated from national gross output and national final demand by determination of the proportion of national value added produced in the region and the proportion of national personal income earned in the region. That is, if we let:

X_i = national gross output industry i
XR_i =regional gross output industry i
VA_i = national value added industry i
VAR_i =regional value added industry i

then, $$XR_i = \frac{VAR_i}{VA_i} (X_i)$$

This assumes that gross output is spatially distributed as value added, and if:

Y_i = national final demand industry i
YR_i = regional final demand industry i
PI_i = national personal income industry i
PIR_i =regional personal income in industry i

then, $$YR_i = \frac{PIR_i}{PI_i} (Y_i),$$

with a similar assumption about final demand (household demand in this case) and personal income. Other measures such as sales and government employment can also be utilized where appropriate. The national figures are available from the OBE's national tables. The regional values are derived as follows:

Using matrix notation, let:

YR = regional final demand
XR = regional gross output vector
X = national gross output vector
A = national flow matrix

Also let:

$$XR = (10 \quad 40 \quad 20 \quad 10)$$
$$X = (100 \quad 2000 \quad 200 \quad 400)$$
$$A = \begin{bmatrix} 20 & 0 & 0 & 40 \\ 0 & 40 & 80 & 40 \\ 0 & 60 & 0 & 0 \\ 20 & 0 & 0 & 200 \end{bmatrix}$$

$YR = (17 \quad 3 \quad 8 \quad 9)$

We first derive the national coefficients matrix by dividing each column by the gross output of the industry represented in the column. This is done by post multiplying the national flow table by the inverse of a diagonal matrix with the values of national gross output along the diagonal. Let:

$\bar{A}$ = national direct coefficient matrix

X^d = diagonal matrix formed from national gross output vector.

$\bar{A} = A(X^d)^{-1}$, then

$$\bar{A} = \begin{bmatrix} 20 & 0 & 0 & .10 \\ 0 & .20 & .40 & .10 \\ 0 & .30 & 0 & 0 \\ .20 & 0 & 0 & .30 \end{bmatrix}$$

The .3 in row 3 column 2 will therefore mean that to produce one unit of industry 2's output requires .3 units of industry 3's output.

Next we derive a regional flow table that represents the flow that would be observed in the region, assuming regional technology, and trade structure to be identical to the national counterparts. That is, this table or matrix assumes the region merely to be a scaled down version of the nation. This first approximation to the desired table is constructed by postmultiplying the national direct coefficient matrix by a diagonal matrix formed from the regional gross output vector.

Let:

RF = regional flow matrix (non-adjusted)

XR^d = diagonal matrix formed from regional gross output vector

$RF = \bar{A} \cdot XR^d$, then

$$RF = \begin{bmatrix} 2 & 0 & 0 & 1 \\ 0 & 8 & 8 & 1 \\ 0 & 12 & 0 & 0 \\ 12 & 0 & 0 & 5 \end{bmatrix}$$

This matrix gives us the intermediate flow necessary to produce the given regional gross output using national technology; it gives no indication as to the source of these flows, that is, whether they are

internal to the region or imported from other regions.

Now if we sum across the rows of the non-adjusted regional flow matrix we obtain intermediate output necessary to produce the given gross output. This intermediate output plus the level of final demand yields the level of output necessary to support regional activity. If we compare this to the level of regional gross output, we can see if the region produces enough itself to support the level of its activity. Using the assumption that the region only imports when it has exhausted its own resources, we compute a vector called net trade balance by subtracting intermediate plus final demand from regional gross output. Positive levels of net trade balance indicate that an industry that produces more than is necessary to support its level of intermediate and final demand will export. Negative levels for net trade balance represent industries that do not produce enough to support the levels of intermediate and final demands and therefore must import. We form the net trade balance vector and then break it into two vectors, commodity imports and commodity exports. The negative net trade balances are imports and the positive are exports.

Let:

NETB = net trade balance vector
CE = commodity exports vector
CI = commodity imports vector, then

$$NETB = (I-\bar{A})\ XR-YR$$

$$NETB = \begin{bmatrix} 10 & -3 & -17 \\ 40 & -17 & -3 \\ 20 & -12 & -8 \\ 10 & -7 & -9 \end{bmatrix} = \begin{bmatrix} -10 \\ 20 \\ 0 \\ -6 \end{bmatrix}$$

$$CE = (\ 0 \quad 20 \quad 0 \quad 0)$$

$$CI = (-10 \quad 0 \quad 0 \quad 6)$$

We have thus derived the level of imports.

In order to derive our adjusted regional direct coefficient matrix we must make an assumption about the allocation of imports among industries. The usual and also most intuitively pleasing assumption is that imports are distributed in the same proportion as flows are of gross output. For example, if the flow from industry one to industry four is one tenth the gross output of industry one, we can assume that industry one accounts for one tenth of the imports of industry one of industry four. We are in effect, saying that the imports are identical to the product produced by the industry, and each purchaser buys imports in relation to his importance as a purchaser. This brings to light the problem that derives from the fact that our region is treated as if it were a single dimensionless point. For a single point there would be no reason to believe that certain pur-

chasers would use greater portions of imports than their output proportion indicates. In reality, industries located at the periphery of the region could be expected to purchase larger portions of imports than anticipated. Also exports would be possible even in an industry that does not produce enough domestically to supply intermediate and final demand. This would be conceivable as industries at the periphery of the region may supply their whole requirements from outside sources, thus releasing internally produced commodities for export from other parts of the region. This problem, due to lack of spatial information about the region itself, is not peculiar to this method and applies to any model that must handle a dimensional entity as a nondimensional point.

Returning to our example, we shall accept the assumption that imports are distributed according to flow proportions of gross output and we derive a matrix indicating these proportions.

Let:

R = row percentages

X_{ij} = flow from i to j

Y_i = final demand industry i, then

$$\bar{R} = \left[X_{ij} \;/\; \sum_j (X_{ij}+Y_i) \right]$$

$$\bar{R} = \begin{bmatrix} .10 & 0 & 0 & .50 \\ 0 & .40 & .40 & .50 \\ 0 & .60 & 0 & 0 \\ .1250 & 0 & 0 & .3125 \end{bmatrix}$$

Multiplying this matrix by the absolute level of imports yields an import matrix showing absolute levels of imports for each cell of the regional flow matrix.

Let:

M = import matrix

CI^d = diagonal matrix with CI vector along diagonal, then

$$M = \bar{R} \cdot CI^d$$

$$M = \begin{bmatrix} 1 & 0 & 0 & .50 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ .750 & 0 & 0 & 1.875 \end{bmatrix}$$

Subtracting this matrix from the regional flow matrix yields an adjusted regional flow matrix representing the internally produced flows for the region. If we let:

$\overline{RF}$ = adjusted regional flow matrix

$\overline{RF}$ = RF-M

$$\overline{RF} = \begin{bmatrix} 1 & 0 & 0 & .50 \\ 0 & 8 & 8 & 1 \\ 0 & 12 & 0 & 0 \\ 1.250 & 0 & 0 & 3.125 \end{bmatrix}$$

This means that, for instance, of the 2 units of flow from industry 1 to industry 2, one of the units is produced by industry 1 in the region and one unit by industry 1 outside the region.

Deriving adjusted regional direct coefficients by dividing each column of $\overline{RF}$ by the appropriate level of output yields a coefficient matrix that can be used to provide the level of output produced in the region necessary to support any level of final demand.

Let:

$\overline{AR}$ = adjusted regional direct coefficient matrix

X_{ij} = adjusted flow from i to j

$$\overline{AR} = \begin{bmatrix} .1000 & 0 & 0 & .0500 \\ 0 & .2000 & .4000 & .1000 \\ 0 & .3000 & 0 & 0 \\ .1250 & 0 & 0 & .3125 \end{bmatrix}$$

MWUF and RWUF Arrays

The next group of input arrays are those two which are used to assign total water use to the specific types of water. They are MWUF, reflecting the proportion of total municipal withdrawal that is fresh, waste, brackish and consumptive in the target year and RWUF, reflecting the proportion of total domestic use that is fresh, waste, brackish and consumptive.

Both of these arrays were generated after a full examination of the existing data and in the case of the RWUF, consultation by the Department of Agriculture. The MWUF array has a factor of 1 for fresh and 0 for waste and brackish. This implies that all municipal withdrawals are of fresh water. The consumptive factor is .05 for all Sub-areas. This figure was adopted after consideration of existing and prospective losses throughout the Region. The .05 implies a 5% consumptive factor. These figures were constant for all objectives and all benchmark years.

The RWUF was derived after examinination of existing data and consultation with the Department of Agriculture. The fresh water factor, for RWUF is 1, waste and brackish are 0. This again implies that the water used is all fresh. The consumptive factor is .20 or 20% for all Sub-areas. The RWUF remains the same for all benchmark years and objectives.

MSAF Array

The MSAF array reflects the proportion of fresh water use in sector (I), Sub-area (J) that is publicly supplied in the target year. The array indicates the percentage of fresh withdrawal publicly supplied to each NAR sector in each Sub-area and is projected for each benchmark year. The array can best be described by the various sectors which have been treated similarly. The agricultural sectors (NAR 1-3) and the mining sectors (NAR 4-7) have, after examination, been assumed to be all self-supplied. The MSAF values for these sectors are 0 for Base Year and all benchmark years. The power cooling sector (NAR 30) is also assumed to be all self-supplied for all Sub-areas for all benchmark years. The wholesale and retail trade sectors (NAR 31-36) because of their locational distribution as assured to be completely publicly supplied for their fresh water needs. MSAF values are 1 for all benchmark years and all Sub-areas. The values for NAR 37, non-agricultural irrigation, were estimated by the NAR Study Group in conjunction with the Department of Agriculture. The values are .1 or .3 depending on the characteristics of the particular Sub-areas and they vary for the benchmark years. The final two sectors of the first group to be considered, NAR 38, 39, are the dummy sectors in the model. They were arbitrarily assigned the value of 1.

The second group of sectors to be examined are the industrial sections. The MSAF array for the industrial sectors (NAR 10-29) was derived from the Cornell Study. Data from the study provided a breakdown of fresh water into Public Fresh and Company Fresh. Company Fresh is analagous to self-supplied fresh water. The data is given by county for 4 digit SIC's. The county values were summed appropriately to give Public Fresh by 2 digit SIC's by Sub-area and Company Fresh by 2 digit SIC's by Sub-area. The MSAF numbers were calculated in 2 steps:

1) Determine Fresh + Company Fresh for each Sub-area and each industry.

2) Take the ratio of Public Fresh to this total for each Sub-area, each industry and each benchmark year.

A further assumption had to be made. The Cornell Study lumps several industries together. These are the industries whose water use in production is minimal. It was necessary to assume that

MSAF for this "Other" category of the Cornell Study is the same for all the relatively-slight water using industries in the model. This was assumed for all benchmark years. The MSAF array was then complete.

When all the input data had been generated preliminary runs were made and distributed for comment and review at the Plan Formulation meetings. Several changes resulted and are useful in illustrating the flexibility of the model methodology.

For example:

SSAM: An error was discovered in the calculation of SSAM for the Sub-area 21c in NAR Sector 16. The error appeared in 1980, 2000, 2020, as well. The entry should have been 0 (zero) as state surveys of this area indicate. However, there were non-zero entries. The adjustment procedure was as follows: Take the entry for 21c reduce it to 0, then distribute the number equally among the non-zero SSAM entries for the remaining Sub-area in NAR 16.

Similar comments were received on many of the data inputs and were adopted into the model, if justified. There were suggestions concerning MSAF changes. For example consider Area 14.

It was remarked that self-supplied fresh water would, after 1980, reach its maximum level in Area 14. Therefore any increment to self-supplied fresh after 1980 had to be shifted to the public sector. This involved the following relationships:

1) 2000 S.S. + 2000 P.S. - [2000 S.S. + 2000 P.S.] MSAF = 1980 S.S.
2) 2020 S.S. + 2020 P.S. - [2020 S.S. + 2020 P.S.] MSAF = 1980 S.S.

Solving these for MSAF we can then make the approximate changes for sectors 10-29. This type of adjustment can be made over and over again if necessary. There is nothing in the derivation procedures of the input arrays to the model which precludes any possible change or refinement or adjustment.

STATE and PSTATE Arrays

The STATE and PSTATE matrices are the simplest input arrays. The STATE array is a 50X3. Each row of the array represents one of the 50 Sub-areas in the NAR. The STATE matrix indicates which state the various Sub-areas are in so that when the model aggregates by states it can apportion the Sub-areas within the proper state boundaries. The matrix was derived by looking at a detailed map of the NAR which showed Sub-area boundaries and state boundaries. It is an alphanumeric matrix in that the entries in each of the 3 columns are the standard state abbreviations. The PSTATE matrix is 50X3. Each row of the PSTATE array again represents one of the 50 Sub-areas in the NAR. The PSTATE matrix, however, has a more complex derivation

than the STATE matrix. PSTATE allocates Sub-area water use among the various states. It would be a decimal figure which, for each row (Sub-areas), adds to one. However, it should be noted serious difficulties arise in assigning one coefficient to allocate water use in all sectors. Because of this, demand model output by state was not utilized.

WCOEF Arrays

A major group of input arrays are those labeled WCOEF. The WCOEF are among the most important arrays in the input data. They represent the state of water use technology and price relationship in the productive process. Their explanation is much more complex and will require several steps. Initially some background information concerning the preliminary work necessary for estimation of WCOEF 1, 2, 3, and 4 will be presented. A detailed examination of the total regional water use coefficients (gal. of any type of water-fresh, waste or brackish/dollar gross output) will then follow. The steps involved in going from total water use coefficients to the fresh, waste, brackish, and consumptive coefficients at the regional level will be outlined. This will be followed by a discussion of Sub-area distribution, projection and adjustment.

The basic formulation of the coefficient is total water use divided by gross output. There are two obvious problems in this formulation. The first is to arrive at a method of calculating gross output and the second is to get estimates of water use. The gross output problem was divided into productive categories. The methodology used will be outlined by categories.

Gross Output Derivation The first two sectors considered are (A) Agriculture and (B) Agricultural Services, Forestry and Fisheries. Since gross output figures were not available, it was necessary to construct a method of estimating gross output for the two sectors. The basic technique used was developed by Bollman and Wood in a series of papers (See "An Evaluation of the Estimates of Gross Domestic Agricultural Output Used in Input-Output Studies", "Estimation of Gross Domestic Output for Agriculture in Each of 11 Western States, 1963", Working Papers 1 and 2, Department of Agriculture, University of California at Berkeley.)

The basic technique is as follows:

Let:

L = cash receipts for livestock products
C = cash receipts from crops
$A = L + C$

$$1 = \frac{L}{A}$$

$$c = \frac{C}{A}$$

H = value of home consumption
N = net change in farm inventories
R = gross rental value of farm dwellings
Q = H + R + N
BW = Bollman-Wood coefficient

This gives us the means for estimating gross output (x)

$$X^{1963}_{NAR} = \left[L^{1963}_{NAR} + \ell Q^{1963}_{NAR} \right] BW_1, \text{ For livestock}$$

$$X^{1963}_{NAR} = \left[C^{1963}_{NAR} + c Q^{1963}_{NAR} \right] BW_2, \text{ For crops}$$

For sector B, a different approach was called for. It was assumed that the ratio of value added to payroll was constant. This implies constant factor shares.

Let P(i) = Taxable payroll for sector i

$$\frac{1964 \quad NAR \quad P(i)}{1959 \quad U.S. \quad P(i)} = \frac{1963 \text{ NAR } VA\ (i)}{1958 \text{ U.S. } VA\ (i)}$$

The payroll figures are available, as is the Value Added figure for 1958. This then gives us the 1963 value added.

The remaining sectors we dealt with included:

C. Construction, Transportation and Finance
D. Wholesale and Retail Trade
E. Services
F. Government Enterprise, Special Industries etc.
G. Mining and Manufacturing

Each subsequent sector will be listed by its letter only and a short summary of the technique used will be given.

Sector C. The method for calculating value added employed here was the same as in sector B.

Sector D. The value added here had to be estimated in an indirect manner. The proxy variable we used for gross output in this sector was total sales (S_i). The value added figure is then obtained in two steps:

1. $$1963 \text{ NAR } X_i = \frac{1958 \text{ U.S. } X_i}{1958 \text{ U.S. } S_i} \times 1963 \text{ NAR } S_i \text{, and}$$

2. $$1963\ NAR\ VA_i = \frac{1958\ U.S.\ VA_i}{1958\ U.S.\ S_i} \times 1963\ NAR\ X_i$$

Sector E. The same method used in D is applied here. The differences being that our proxy is now Total Receipts.

Sector F. The value added was calculated on the basis of an appropriate aggregate variable's (L) growth rate and weighted by an estimate of gross regional product (GRP). First derive GRP:

$$GRP = \frac{\text{Personal Income - NAR}}{1963\ \text{Personal Income - U.S.}} \times \text{GNP 1963}$$

The resulting value added formula was;

$$1963\ NAR\ VA_i = \frac{1963\ L \times GRP}{1958\ L\ \ GNP} \times 1958\ US\ VA_i$$

(L can represent many different aggregate variables)

Sector G. Value added figures are available for this group in two places. There are figures from the Office of Business Economic and from the Bureau of the Census. The problem is that they do not agree with each other. The following adjustment was made:

$$(OBE)\ 1963\ NAR\ VA_i = \frac{1958\ U.S.\ VA_i\ (OBE)}{1963\ U.S.\ VA_i\ (Census)} \times 1963\ NAR\ VA\ (Census)$$

Then to derive gross output:

$$1963\ NAR\ X_i\ \frac{1958\ U.S.\ XI}{1958\ va_i\ (OBE)} \times 1963\ NAR\ (OBE)$$

This then is the groundwork for the calculation of the Total Water Use Coefficients. The calculation of the actual coefficients will be detailed by activity groups of sectors.

The first group of coefficients are the total water use group. Total includes the fresh, waste, brackish, and consumptive values. The total group will be developed first and then the four other groups will be derived from it. In discussing the total coefficients they will be grouped according to methodologies used rather than according to the type of output generated in the particular NAR sector. The source for the relevant data in all cases will be found at the end of the methodology.

Agricultural Sectors. The first NAR sector to be looked at are NAR 1, and 2, and 3. These are the agricultural sectors. The gross output figures were calculated by the above procedure. Water

use data is provided by the Department of Agriculture. The standard method:

$$\frac{\text{Total water use}}{\text{Gross output}} = \text{Total water use coefficients}$$

was used to calculate the coefficients. For NAR 2 the water use data needed some adjustments. For consistency, the data on water use due to irrigation had to be adjusted to 1963 levels. This was done by an interpolation procedure. This is possible because water requirements remain constant over all the region (one foot per acre). The method was to assume a constant growth rate in the amount of land irrigated in the period 1959-1964. Then using the 1959 figures as the base value the 1963 figure becomes:

$$\text{1963 Gross requirements} = (\text{1964 G.R.} - \text{1958 G.R.}) \times \frac{1963-1959}{1964-1959} + \text{1959 G.R.}$$

$$= (277{,}900 - 203{,}000) \times \frac{4}{5} + \text{1959 G.R.}$$

$$= 262{,}800 \text{ acre feet}$$

$$= 85{,}700 \text{ million gallons.}$$

The total water use coefficient was then derived in the standard manner.

For NAR 3 a yet different approach was required. It was necessary to make the assumption that total water use is directly related to the employment level in this sector. In this particular sector, the employment figure had to be weighted by the length of the growing seasons. The employment figure was obtained by interpolating between the 1960 figures and the estimated figures. The basic formulation is similar to NAR 2:

Let E=Employment,

$$\text{then } 1963\ E = 1960\ E \div \left[1980\ E - (1960\ E)\left(\frac{1963-1960}{1980-1960}\right)\right]$$

It was then necessary to get the average growing season length for the whole NAR. This was done in this manner:

Let X_i= employment in the i'th Sub-area
Y_i=length of growing season in the i'th Sub-area
F = average growing season length for the whole NAR

$$\text{then,} \quad F = \frac{\sum_{i=1}^{50} (X_i\ y_i)}{\sum_{i=1}^{50} (X_i)}$$

Employment and the length of the growing season are known. To get an

estimate of total water use a technique outline in Lofting's paper was used. It was assumed the average employee uses 30 gal/day. Then to get total water use:

Total water use=FxEx 30 gal/day.

The total water use coefficient is then calculated in the standard manner.

Mineral Industries. The next group-NAR 4,5,6,7,-the mineral industries, presented a different type of problem. Gross output data is calculated as before. The problem arises in that the water use figures are not disaggregated enough. They are not broken down into water use for each industry for each state. It was therefore necessary to disaggrate them into water use by industry for each state. The water was distributed in this manner. The Bureau of Mines "Water Use in the Mineral Industry" gives the gallons of water per dollar value added for 4 place SIC codes for each state for NAR 4, 5 and 7. The commodities listed were sorted into their various SIC groups by referring to the SIC Manual, 1967. Value added for each commodity for each state was then multiplied by the gallons per dollar value added from the Bureau of Mines booklet. This gave gallons of water used for each commodity mined in each state. To get the NAR totals, gallons by SIC two digit codes were summed.

This procedure was applied to all values to get water use for each NAR sector for each state. These values were summed to get total water use for each NAR sector. Water use then is distributed and gross output figures are available. The standard procedure is used to calculate the coefficients. The same procedure was followed for NAR 6.

Manufacturing Industries. NAR sectors 10-29, were the next group. NAR sectors 10, 12, 16, 18-29 were all dealt with in the same manner. Value added and water use figures are readily available. In the water use figures there is an understatement because there is a minimum water usage requirement before a firm is counted in the census. In some of the NAR sectors there were gross output figures available without corresponding water use data. In the great majority of the cases, the gross output was small enough so that the water use figure was below the census threshold level. In some instances, however, this was not the case. The gross output was large enough to have an appreciable impact on the water use coefficient (at least a factor of 10%). The approach to this was a little more difficult. Because 2 digit SIC groups were used, a clear breakdown of the different productive processes in an industry was difficult. Some of these processes may be water intensive, others, not at all. Water use data would exist for some areas but not others.

Consider NAR 19- Petroleum Refining and Related Industries. The water use figures are available only for two states in the whole

NAR, yet there are gross output figures for 5 others which are about 20% of total gross output. Looking at the 4 digit SIC code as available in the Census of Manufactures no reason is apparent. The two states with water use figures are Pennsylvania and New Jersey, both of which have large petroleum refining industries which use water in the productive process. The other 5 states, however, are engaged primarily in producing asphalt, road surfacing materials and other derivatives. The productive processes for this type of industrial output involves little water. The requirement might be low enough to keep the figures below the census threshold. This would tend to reduce all the resulting coefficients.

The standard procedure was followed for sectors 10, 12, 16 and 18-29 and the total coefficients were then calculated. The remaining NAR sectors 11, 13, 14, 15, and 17 had to be approached differently. Gross output figures were available. The problems arose when trying to get water use data. In the case of these sectors, there is very little water used in the productive process. What was done, as suggested by Lofting in his paper, was to attribute an average figure for water use by each employee per day. This then was multiplied by the number of employees and number of working days to give us total water use. The standard procedure was then followed.

This summarizes the first 29 NAR sectors with the exception of NAR 8 and NAR 9. In NAR 8, since regional estimates are not available, the national water use coefficient was computed and it was assumed that it held for the Region. This is based on the following assumptions:

Let

A = number of barrels of gypsum used per year
B = pound of gypsum per barrel
C = water requirement for 1 pound of gypsum
D = total water used per year for gypsum

$$D = A \times B \times C$$

The same was done for cement, and then figures for curing and cleaning were estimated. It was assumed, following Lofting's outline, that the water used for curing and cleaning is equivalent in amount to the water used for mixing. The sum of these three components (cement + gypsum + curing and cleaning) gives us total water use. Gross output is known. The standard procedure then applies.

The case of NAR 9, Ordinance and Accessories, was more difficult to deal with. Water use figures are not available for this sector. There are two ways of dealing with this problem, and both depend on the ability to pick another NAR sector with similar water requirements in production. The first method is to look for this

sector, calculate its water use coefficient and assume it for NAR 9. This method was adopted with the coefficient for NAR 25 assumed valid for NAR 9. The second, which is a way of checking and allowing for possible differences due to differences in gross output (there may be scale differences), is to get water per employee in an industry we assume has a similar productive process. Since employment figures are available for NAR 9, we can get total water use by multiplying water/employee x employees. This provided a reasonable check on the adopted method.

Power Cooling. NAR 30 is the next sector. It included transportation and warehousing, communication except radio and T.V. broadcasting, and electric, gas, water and sanitary services as well as power generation. It was necessary to divide the sector into two parts in order to get estimates of water use. The first part included transportation and warehousing, communication except radio and T.V. broadcasting, and electric gas and sanitary Services. Water use figures were not available for these industries. What was done was to follow the Lofting procedure of estimating it by employees and the number of days in a work year. The second grouping was water used for power generation. The water use figures for power generation were readily available. Gross output is also available. Summing the two groups and using the standard procedure gives the total water use coefficient.

Service Sectors. The next group, NAR 31-36, were all calculated in the same manner. Since water use data were not available for these industries, it was necessary to attribute a certain water use per employee and repeat the process for generating total water use figures. Gross output was available. The calculation of the coefficients followed the standard procedure.

Sectors 37, 38, 39 are dummy sectors and have been assigned the value 0. The total water use coefficients for all 39 sectors have been outlined. It remains to discuss the procedures for breaking down the total coefficients into the 4 sub-categories of fresh, waste, brackish, and fresh consumptive.

Disaggregation of Total Regional Coefficients. The general procedure for disaggregating the total water use coefficient into the four basic categories was a relatively simple one. Since in 19 of the 36 NAR divisions the regional water use data was reported in the various categories concerned, a simple proportion was needed to calculate the coefficients. For example, for fresh water the proportion used was as follows:

$$\frac{\text{Fresh water used}}{\text{Total water used}} = \frac{\text{Fresh water use coefficient}}{\text{total water use coefficient}}$$

This can be rewritten in the form of an identity from the definition of fresh water use coefficient and total water use coefficient.

Fresh water use coefficient=fresh water use/gross output

Total water use coefficient=total water use/gross output

then:

$$\frac{\frac{\text{fresh water use}}{\text{gross output}}}{\frac{\text{total water use}}{\text{gross output}}} = \frac{\text{fresh water use}}{\text{total water use}},$$

since the gross output is the same in both coefficients.

This procedure was applied to NAR 4,6,10,12,16 and 18-29 for all four coefficients. The derivation of the coefficients for the metal mining industry, NAR 4, needs a further expansion. The ratio of fresh consumption to fresh water use was calculated in a different manner. The figures were available by SIC for the NAR sector on the national level. The ratio of water consumed/new water could be calculated. This was assumed to be our consumptive ratio for NAR sector 4.

In NAR 6, using "Water Use in the Petroleum and Natural Gas Industries", the following information was available: % Brackish, % Waste and % Consumptive. However, from Table 15, natural gas processing had to be eliminated from the calculations as it fell outside the NAR. The percentages had to be recalculated. To get the percent of fresh consumed, another manipulation was necessary. The percent of new water consumed in the sector by the type of industry involved (well-drilling, secondary recovery and natural gas processing) was available. The percent of new water which is fresh by industry type was also available. It was then assumed that if an industry consumes 80 percent of its new water, it will consume 80 percent of its fresh water. This assumption is not as serious as it appears. The percent of consumption of new water in well-drilling is 100. Therefore, the percent fresh consumed is also 100. Natural gas processing is assumed 0.

Operation	New Water Input	New Water Consumed	%Consumed
Well-Drilling	321,922	321,922	100
Secondary-Recovery	2,571,826	2,310,869	90
	2,893,748	2,632,791	91

Operation	Fresh	Saline	Total New Water	Fresh/Total
Drilling	283,519	38,403	321,922	88%
	1,893,748	1,354,266	2,571,826	47%

Assuming % Fresh Consumed = % New Consumed:

	% New Consumed	% Fresh Consumed
Well Drilling	100	100
Secondary Recovery	90	90

Therefore, in case of drilling, if 100% new consumption, then 100% fresh consumption is necessarily true.

In the case of secondary recovery, if there is 90 percent new consumption, the maximum error of our assumption will occur when all saline is consumed and only then is fresh consumed. As given in the referenced publication on water use, 53 percent of the new water consumed is saline and only 37 percent is fresh. This implies a fresh consumption percentage of 79% or at most an 11% error.

As in the previous estimation of the total water use coefficient, NAR 9 was assumed to have the same values as NAR 25.

NAR 1,2, and 3, the agricultural sectors, required a different procedure. The total water use in these sectors is all fresh water. Therefore the total water use coefficient and the fresh water use coefficient are equal. In the case of NAR 1, and 2, the amount of water consumed is equal to the amount of water used. This can be attributed to the nature of these sectors - Livestock and Livestock Products and Other Agricultural Products. The remaining sector, NAR 3, is the agricultural services sector. It also uses only fresh water so its fresh water use coefficient would be the same as its total water use coefficient. It differs however, in that all of its water use is not consumptive. Using an estimated value of 5% consumption, we can get the consumptive coefficient.

Let a=total water use
x=gross output
y=consumptive coefficient

Then:

$$y = \frac{.05a}{x}$$

The brackish and waste coefficients are = 0.

This leaves NAR sectors 5,7,8,11,13,14,15,17,30 and 31-36. NAR 11,13,14,15,17 and 31-36 have all been handled in the same way. These particular sectors are either service sectors (31-36) or manufacturing sectors whose sole water use is by and for employees rather than in the productive process. The water used then is all fresh water, and the total water use coefficient is equal to the fresh water use coefficient. Using the 5% estimated consumption figure, we can get the consumptive coefficient. In the case of NAR 8, all fresh water use was assumed, with 100% consumption. Since the mixing of cement and gypsum and the subsequent curing and cleaning process are done

with fresh water only, the total water use coefficient equals the fresh water use coefficient. The water used is also totally consumed due to the nature of the industry. Therefore the consumptive use coefficient equals the fresh water use coefficient.

This then is the WCOEF 1,2,3 and 4 methodology with exception of NAR sectors 5,7 and 30. The procedures used for these sectors will be covered in the following section on disaggregation into Sub-areas.

Sub-area Distribution. For NAR sectors 1-4,6,8, and 31-36 it was assumed that the regional coefficients applied to the Sub-areas. This is believed reasonable since in the case of 1-4,6, and 8, the productive process doesn't appreciably vary due to location and for 31-36, the coefficients are based on employee water use, which is also relatively constant throughout the region.

Coefficients for sectors 5 and 7 had to be developed on the basis of information provided by the Bureau of Mines. The data were received in this form. For each of the 21 Areas, a water use value in MGD's for sectors 5 and 7 combined was listed. The data had to be arranged in a more useful form. This was done in three steps:

1) Sum the percentage of NAR total employment found in Area (I) in sector 5 and the corresponding number for sector 7. Then take the ratio of this percentage of sector 5 employment in Area I to this newly formed total. Do this for sector 7 as well. Repeat for all 21 Areas. This gave the percentage of the total employment in sectors 5 and 7. Using employment as a measure of output, multiply the water use data from the Bureau of Mines by these newly calculated percentages. This gives the water use in NAR 5 and water use in NAR 7 by the 21 Areas.

2) It was necessary to disaggregate these figures into the water used for NAR 5 and for NAR 7 in each of the 50 Sub-areas. This was done in this manner. Take the ratio of the percentage employment in NAR 5 found in Sub-area (J) to the percentage employment in NAR 5 found in the Area in which Sub-area (J) is located. Repeat this procedure for all Sub-areas. Then multiply the water use in NAR 5 for each Area by these numbers. Repeat for NAR 7.

3) The third step was to determine coefficients by dividing the calculated water use by Sub-area gross output.

The coefficients for sector 30 were based on information supplied by the Federal Power Commission. The FPC supplied data for each Sub-area. The Sub-area gross output (SBGOV) was available from the model. For each of the 50 Sub-areas the following ratios were formed:

$\frac{\text{Fresh}}{\text{SBGOV}}$ = Fresh Water Use Coefficient

$\frac{\text{Brackish \& Saline}}{\text{SBGOV}}$ = Brackish Water Use Coefficient

$\frac{\text{Fresh Consumption}}{\text{SBGOV}}$ = Consumptive Water Use Coefficient

These were the water use coefficients for sector 30.

The available data for distributing coefficients for sectors 9-29 is as follows:

1. Total NAR Water Use Coefficients derived from the Water Use in Manufacturing and Value Added figures, modified by the relationship of gross output to value added have been constructed for each benchmark year.

2. Total water intake by 4 digit SIC's by Sub-area and brackish water intake by 4 digit SIC's by Sub-area are available from the Cornell Study.

The question arose as to how to calculate the water use coefficients for each Sub-area for each manufacturing industrial classification. It was decided to develop a way of distributing the total water use coefficients using the distribution developed by the Cornell Study.

Total and brackish will be used to get a fresh water use coefficient.

Consider the identity:

$$(1) \quad T_i = B_i + F_i + W_i$$

Where:

$T_i \equiv$ Total NAR Intake of Industry i

$B_i \equiv$ Total Brackish NAR Intake of Industry i

$F_i \equiv$ Fresh NAR Intake of Industry i

$W_i \equiv$ Waste NAR Intake of Industry i

W_i, however, is 0 for all i, therefore equation (1) becomes:

$$T_i = B_i + F_i$$

Now, $T_i = \sum_j t_{ij}$

$B_i = \sum_j b_{ij}$

$F_i = \sum_j f_{ij}$

where : $t_{ij} \equiv$ total intake of i in Sub-area j

$b_{ij} \equiv$ brackish intake of i in Sub-area j

$f_{ij} \equiv$ fresh intake of i in Sub-area j

then for any subregion

$$t_{ij} = b_{ij} + f_{ij} \quad \text{and}$$

$$(2) \quad t_{ij} - b_{ij} = f_{ij},$$

What is needed is some way of distributing the total water use coefficient to the Sub-areas. One method is to get the percentage of total and brackish intake in the Sub-area.

Consider $$\frac{t_{ij}}{T_i} - \frac{b_{ij}}{T_i} = \frac{f_{ij}}{T_i}$$

then:

$$(3) \qquad \frac{t_{ij}}{T_i} T^* - \frac{b_{ij}}{T_i} T^* = \frac{f_{ij}}{T_i} T^*$$

where $T^* \equiv$ Total water use coefficient

A further modification is needed. The sub-area coefficients are water use/gross output.

$\frac{t_{ij}}{T_i}$ gives us the percent of total intake of i in Sub-area j. When T^* is multiplied by this, the result is:

$$T^* = \frac{\text{total water used in i in j}}{\text{Gross Output for the whole NAR}}$$

A distributor for gross output must also be included. The distributor used is the percent of employment of i in j or the SSAM. Then equation 3 becomes:

(4)

$$\frac{\frac{t_{ij}}{T_i}}{\frac{e_{ij}}{\sum_j e_{ij}}} T^* - \frac{\frac{b_{ij}}{T_i}}{\frac{e_{ij}}{\sum_j e_{ij}}} T^* = \frac{\frac{f_{ij}}{T_i}}{\frac{e_{ij}}{\sum_j e_{ij}}} T^*$$

Equation (4) seems to be the distributor, but must be examined as to what these variables are in relation to the Cornell work. From this work

(5) $t_{ij} = \sum_f (\hat{e}_{ijz} W_z)$

Where: $\hat{e}_{ijz}$ is estimated 4 Digit SIC Employment of Industry i in Sub-Region j. W_z is water use per employee ratio for each 4 digit SIC of i in j.

$\sum_z (\hat{e}_{ijf} W_z)$

Is the sum of all 4 digit Total water Intake or the total water Intake at the 2 digit level.

$$(6) \qquad T_i = \sum_j \sum_z (\hat{e}_{ijz} \, w_\tau)$$

Where: $\sum_z (\hat{e}_{ijz} \, w_\tau)$ is defined as above $\sum_j \sum_z (\hat{e}_{ijz} \, w_\tau)$ is the total water intake of i in j summed over j or the total water use of industry i for the whole NAR.

The gross output distributor should be further explained. It is derived from the Cornell work. That Study has distributions of employment by 4 digit SIC's. It then estimates 4 digit level employment. The SSAM distributor is refined as 2 digit SIC employment. The "new" relationship then becomes:

$$(7) \qquad \frac{e_{ij}}{\sum_j e_{ij}} = \frac{\sum_z \hat{e}_{ijz}}{\sum_j \sum_z \hat{e}_{ijz}}$$

Where e_{ijz} = estimated 4 digit SIC employment of i in J. $\sum_z \hat{e}_{ijz} \equiv$ estimate 2 digit SIC employment of i in j

$\therefore \sum_j \sum_z \hat{e}_{ijz} \equiv$ Total NAR employment in Industry i

Then Equation (4) becomes:

$$(8) \qquad \frac{\sum_z (\hat{e}_{ijz} \, w_z)}{\sum_j \sum_z (\hat{e}_{ijz} \, w_\tau)} T^* - \frac{b_{ij}}{\frac{\sum_z (\hat{e}_{ijz})}{\sum_j \sum_z (\hat{e}_{ijz})}} T^* = \frac{f_{ij}}{\frac{\sum_z (\hat{e}_{ijz})}{\sum_j \sum_z (\hat{e}_{ijz})}}$$

This is the distributor that was used.

Two problems remain:

1. Is this conceptually correct?

2. Does it give the same result if compared to gross output multiplied by a hand calculated coefficient?

Conceptually we want to have a total water use coefficient, distributed by some method, multiplied by gross output. This then is:

(9) $T^* \, GO_i^* \, \frac{t_{ij}}{T_i} = T^* \, GO_i^* \, \frac{\sum_z (e_{ij} \, w_z)}{\sum_j \sum_z (\hat{e}_{ijz} \, W_z)}$ Where: $GO_i^* \equiv$ Gross Output of industry i in the NAR

Then $T^* \, GO^*$ gives total water intake. $\frac{t_{ij}}{T_i}$ is the percent of total water intake of i in j. The product is then the total intake of i in j
It must be shown that our distributor gives the same results.

From equation (8):

$$\frac{\dfrac{\sum_z (\hat{e}_{ijz} \, w_z)}{\sum_j \sum_z (\hat{e}_{ijz} \, w_z)}}{\dfrac{\sum_z (\hat{e}_{ijz})}{\sum_j \sum_z (\hat{e}_{ijz})}} \, T^* \, GO_{ij}^*$$

Where: $GO_{ij}^* \equiv$ Gross Output of i in j
and: $GO_{ij}^* =$ SSAM GO_i^*

$\therefore$ (10) becomes:

$$\frac{\dfrac{\sum_z (\hat{e}_{ijz} \, w_z)}{\sum_j \sum_z (\hat{e}_{ijz} \, w_z)}}{\dfrac{\sum_z (\hat{e}_{ijz})}{\sum_j \sum_z (\hat{e}_{ijz})}} \, T^* \, \frac{\sum_z \hat{e}_{ijz}}{\sum_j \sum_z \hat{e}_{ijz}} \, GO_i^* = T^* GO_i^* \, \frac{\sum_z (\hat{e}_{ijz} \, W_z)}{\sum_j \sum_z (\hat{e}_{ijz} \, W_z)}$$

which is exactly equivalent to equation (9).

Therefore, our distributor is conceptually correct. This brings us to the second problem; does the sum of the distributed coefficients multiplied by gross output give the same total intake as the total coefficient multiplied by gross output.

For total intake does

$$(11) \qquad \sum_{j} \left[T^{*} \left(\frac{\dfrac{\sum_{z} (\hat{e}_{ijz} W_{z})}{\sum_{j} \sum_{z} (\hat{e}_{ijz} W_{z})}}{\dfrac{\sum_{z} (\hat{e}_{ijz})}{\sum_{j} \sum_{z} (\hat{e}_{ijz})}} \right) GO_{ij}^{*} \right] \overset{?}{=} T^{*} GO_{i}$$

Now

$$\sum_{j} \left[\frac{\sum_{z} (\hat{e}_{ijz} W_{z})}{\sum_{j} \sum_{z} (\hat{e}_{ijz} W_{z})} \right] = 1$$

$$\sum_{j} \left[\frac{\sum_{z} \hat{e}_{ijz}}{\sum_{j} \sum_{z} \hat{e}_{ijz}} \right] = 1$$

And

$$GO_{ij}^{*} = \frac{\sum_{z} \hat{e}_{ijz}}{\sum_{j} \sum_{z} \hat{e}_{ijz}} GO_{i}^{*}$$

$$\therefore \quad \sum_{j} GO_{ij}^{*} = GO_{i}^{*}$$

Therefore, 11 becomes:

$$T^* \times GO^*_i \quad \frac{1}{1} \quad \stackrel{?}{=} \quad T^* \times GO^*_i$$

$$T^* \; GO^*_i \quad \stackrel{\checkmark}{=} \quad T^* \times GO^*_i$$

For brackish intake does

$$(12) \quad \sum_j \left[T^* \left(\frac{\dfrac{b_{ij}}{\sum_j \sum_z (\hat{e}_{ijz} \; W_z)}}{\dfrac{\sum_z (\hat{e}_{ijz})}{\sum_j \sum_z (\hat{e}_{ijz})}} \right) \quad GO^*_{ij} \right] \stackrel{?}{=} B^* \times GO^*$$

<u>Where</u>:

$B^* \equiv$ Brackish water coefficient

Now: $\sum_j b_{ij} = b_i$

$$\sum_i \left[\sum_j \sum_z (\hat{e}_{ijz} \; W_z) \right] = \sum_j \sum_z (\hat{e}_{ijz} \; W_z)$$

$$\sum_j GO^*_{ij} = GO^*_i$$

Therefore 12 becomes:

$$(13) \quad \frac{b_i}{\sum_j \sum_z (\hat{e}_{ijz} \; W_z)} \; T^* \times GO^*_i \stackrel{?}{=} B^* \times GO^*_i$$

But:

$B^* \equiv T^* \times \frac{b_i}{T_i}$ since $T^* = \frac{T_i}{GO_i}$ and $\frac{T_i}{GO_i} \times \frac{b_i}{T_i} = \frac{b_i}{GO_i}$ which

is our brackish coefficient. $b_i = B_i$

and $T_i = \sum_j \sum_z (\hat{e}_{ijz} \; w_z)$ $\therefore$ $B^* = T^* \times \dfrac{b_i}{\sum_j \sum_z (\hat{e}_{ijz} \; w_z)}$

and 13 becomes:

$$\frac{b_{ij}}{\sum_j \sum_z (\hat{e}_{ijz} \; w_z)} \times T^* GO_i^* \cancel{=} T^* GO_i^* \times \frac{b_i}{\sum_j \sum_z (\hat{e}_{ijz} \; w_z)}$$

Therefore, the distributor is conceptually valid and gives the proper relation when summed. The distributor was then applied to the NAR total water use coefficients for sectors 10-29, the industrial sectors, in order to get the fresh and brackish coefficients for each Sub-area and each sector. The consumptive coefficient was then

$$\frac{C_{ij}}{T_i} \quad T^*$$

where c_{ij} = consumptive use of industry in sub-basin j.

WCOEF Projections. The WCOEF 1,2,3,4 materials had to be projected for the future benchmark years and objectives. NAR 5,7 and 30 were projected on the basis of the data supplied by the Bureau of Mines and the Federal Power Commission. The Department of Agriculture provided the water use figures for NAR 1,2 by benchmark year and objective. The gross output was available from the model. The usual procedure in calculating the coefficients was applied. The remaining sectors can be broken down into three major areas depending on how the initial coefficients were derived. The first group of sectors are those whose coefficients were estimated by the imputed water use per employee method. This included the following sectors: 3,11,13,14, 15,17 and 31-36. It was assumed that the relationship between the number of employees, gross output and water use would remain fairly stable over time. This follows from the observation that employment is the sole source of water use in these industries.

The second group included those NAR sectors which had very small amounts of water used in the productive process, and whose resulting water use coefficients were very small. These included NAR sectors 4,6,9,20,21,24,25,26,27,28, and 29. After a detailed examination into the productive processes employed by these various industrial sectors, it was felt that in the future any change in water use per dollar gross output would be minimal. In light of the projection problems involved it would be reasonable to assume that these coefficients would remain the same for all benchmark years and all objectives. Because of a lack of detailed information and the nature of the estimating process for the coefficient, it was also assumed that NAR 8 would have essentially the same relationship between water use and gross output in the future as now exists. (There are shortcomings to these procedures-for example, water use per employee may increase rapidly due to widespread air conditioning use. However, given the available information and the difficulty of projecting changes in technology and in light of the size of water use in these industries, these assumptions are not unjustifiable.)

The third group of industries to be considered are those of the heavy water using industries. These included NAR 10,12,19,23, 16 and 18. Consider the first four sectors NAR 10,12,19, and 23. The water use coefficients reflect the level of water using technology in the industry. Technological change is not an even going process. It does not occur at a constant rate but rather at an accelerating rate. This is even more true in relation to technology involving water use. The typical water saving technology does not usually result in marked reduction in costs of production nor in large increases in output, and as a result does not usually have the cost reducing incentive for its adoption. Technological change in heavy water using industries will occur for one of two reasons:

1) water supplies are no longer available or cannot be expanded
2) political climate is such that the changes are, in fact, mandated.

The second reason is the one that applies primarily to NAR 10,12,19 and 23. Therefore, 2) in combination with 1) led to the conclusion that water saving innovations would be introduced for all objectives, at a rate which would allow for a reduction of water use per dollar output by about 5% from 1965 to 1980, by 10% from 1965 to 2000 and by 20 percent from 1965 to 2020.

Sectors 16 and 18 involved the inclusion of industry estimates. During the plan formulation meetings it was indicated that the original NAR estimates for these two sectors were much too high. The reasons given were that:

1) available water supply could not be increased greatly enough to meet the projected demand

2) these industries were finding it necessary to reduce water use by introducing technological changes even though these changes were not leading to reduced costs

The resulting estimates of technological changes in these industries indicate that technological change is an accelerating process. The actual changes for all objectives took this form. The reduction in water use for NAR 16 was 10 percent from 1964 to 1980, 30 percent from 1965 to 2000 and 50 percent from 1965 to 2020. The respective changes for NAR 18 were 15 percent, 45 percent and 75 percent.

WCOEF Adjustments. After the initial coefficients were developed, preliminary computer runs were made and the results submitted to the participating states and agencies at the plan formulation meetings. As a result of the discussions, several additional adjustments and refinements in the WCOEF matrices were made.

The first set of adjustments had to be made in the Connecticut River Basin, and the changes involved taking into account water use which had previously gone undetected. (Possibly due to limitations in the Census of Manufactures, Water Use in Manufacturing). The changes in general involved adding a certain number of mgd's for a particular industry in a particular Sub-area. The method used, in general, was as follows: Take the existing mgd value and add the required amount to get the desired level of water use. Then use the following equation to get the necessary

water use coefficient

Sub-Area Gross Output X Water Use Coefficient = Water Use

This was done for the following sectors and Sub-areas:

SECTOR	SUB-AREA
16	8a,8b
24	8b,8c
12	8c
25	8c
27	8d

The resulting coefficients had to be projected for 1980, 2000 and 2020. This was accomplished by applying the same percentage change between 1964-1980, 1980-2000, 2000-2020 to the newly calculated coefficients as was applied in the original coefficient projections.

The next river basin adjusted was the Delaware River Basin. The coefficients were adjusted on the basis of a Delaware River Basin Commission inventory of water-using industries. Water use in 1964, in mgd's, was taken from this inventory. These values were the actual ones and the coefficients were adjusted using the same relationship as above to get coefficients for 1964 in the following sectors and Sub-areas:

Sector	Sub-Area
16	15c,15d
18	15b,15c
19	15d
22	15b,15d
23	15b,15c,15d

These new coefficients were projected into the future by applying the same percentage changes that were applied to the previous coefficients.

The same procedure was used for the Susquehanna River Basin. It was applied to the following sectors and Sub-areas:

Sector	Sub-Area
10	17a
12	17b
16	17c
18	17d
19	17e
23	17e
24	17e

Future projections were made as before.

There were several other subsequent coefficient changes which were made. They were done in the same manner and will just be listed.

Sector	Sub-Area	WCOEF
23	18a	3
23	18a	2
18	14	1
18	14	3

The projected values were arrived at in the same procedure as before.

REFERENCE SOURCES

Input Data Items

1) Office of Business Economics, Populations, Personal Income and Earnings Projected for Selected years and Office of Business Economics, Projections of Gross National Product, found in Appendix B, Economic Base; North Atlantic Regional Water Resources Study.

Input Data by Rows or Columns

1) County and City Data Book 1967 U.S. Bureau of Census, Department of Commerce.

2) Growth Patterns in Employment by County; Volumes I, II and V, United States Office of Business Economics, Department of Commerce 1965.

3) Appendix B, Economic Base, North Atlantic Regional Water Resources Study, 1971.

AGIR, NAGIR, CROPIR, AGWS, AWSSF, OTIR

U.S. Department of Agriculture estimates

BMWU

North Eastern Water Supply inventory provided by the NEWS study group.

RFDDV

1) Survey of Current Business, United States Department of Commerce, Office of Business Economics, September 1965.

SAPCL

1) Federal Power Commission, also found in Appendix P, Power, North Atlantic Regional Water Resource Study.

SAIL

1) Industrial Water Use in the North Atlantic Region, Rollins N.W., and Allee, D.J. Marine Sciences Center, Ithaca, New York.

Input Data Arrays

MSAF, SSAM

1) Industrial Water Use in the North Atlantic Region, Rollins, Allee and Lawson, etc.

2) County Business Patterns 1964 Bureau of the Census, U.S. Department of Commerce.

STATE, PSTATE

1) County and City Data Book, 1967, U.S. Bureau of the Census, Department of Commerce.

RICM

1) Fortune's 1966 Input/Output Matrix: Time Inc.

2) Moore, Frederick T. and James W. Petersen: "An Interindustry Model of Utah", U.S. Department of the Interior, Interindustry Miscellaneous Paper Number 78, October 1953.

3) "Input-Output Structure of the U.S. Economy, 1963", Survey of Current Business, November 1969.

WCOEF Arrays - Gross Output Derivation

Sector	Source
A (Agriculture)	Bollman and Wood, "An Evaluation of the Estimate of Gross Domestic Agricultural Output as Used in Input-Output Studies with Particular Reference to the Western States", Working Paper 1, University of California. Bollman and Wood "Estimation of Gross Domestic Output for Agriculture for Each of 11 Western States, 1963", Working Paper 2, University of California at Berkeley. U.S. Bureau of the Census; County and City Data Book, 1967, U.S. Government Printing Office, 1967. U.S. Department of Agriculture Economic Research Service, Farm Income-State Estimates 1959-65, FIS203, Supplement 8/66.
B (Agricultural Services, Forestry	U.S. Bureau of the Census, County Business Patterns 1964 U.S. Summary, U.S. Government Printing Office, 1965. U.S. Department of Commerce, County Business Patterns First Quarter 1959, Part I, U.S. Summary, U.S. Government Printing Office 1961.
C (Construction, Transportation, Finance)	U.S. Bureau of the Census, County Business Patterns 1964 (By State), U.S. Government Printing Office, 1965.
D (Wholesale and Retail Trade)	U.S. Bureau of the Census, 1963 Census of Business Wholesale and Retail Trade (By State) U.S. Government Printing Office 1965.
E (Services)	U.S. Bureau of the Census, 1963 Census of Business, Selected Services, U.S. Government Printing Office, 1965.
F (Government Enterprise, Special Industries)	Office of Business Economics, U.S. Department of Commerce, The National Income and Product Accounts of the United States 1929-65, Statistical Tables, U.S. Government Printing Office, 1966.

G	Office of Business Economics, U.S. Department of Commerce, Survey of Current Business
(Mining and Manufacturing)	(1958 Input-Output Study) Volume 45 No. 9 9/65.
	U.S. Bureau of the Census, U.S. Census of Mineral Industries, 1958, Volume I, Summary and Industry Statistics, U.S. Government Printing Office, 1961.

Sources for Total Water Use Coefficient Data
(The sources will be listed for each NAR sector)

NAR	Data Type	Source
1	Water Use	Preliminary Issue-Rural Domestic and Livestock Water Requirements
2	Water Use	First Draft. NAR Appendix I, May 1968
3	Water Use	"Economic Evaluation of Water", E.M. Lofting, U. of California at Berkeley
	Growing Season	United States Department of Agriculture, Growing Season Data by Sub-region.
	Employment	Final Draft, Appendix B, NAR Study.
4,5,7	Water Use	United States Department of Interior Water Use in the Mineral Industry, by A. Kaufman and M. Nadler
	Value Added	United States Bureau of the Census, 1963, Census of Minerals Industries
6	Water Use	United States Department of Interior, Water Use in the Petroleum and Natural Gas Industry, Paul Buttermore.
8	Water Use	"Economic Evaluation of Water" E.M. Lofting U. of California, Berkeley
	Cement and Gypsum Tonnage	Statistical Abstract of the United States 1967, U. S. Bureau of the Census
9	Employment	Bureau of Labor Statistics Bulletins 1370-5 Employment and Earnings Statistics for Areas, 1963-67
10,12	Water Use	Bureau of Census, 1963 Census of Manufactures

16,18,29		Water Use in Manufacturing
11,13,14	Employment	U.S. Bureau of the Census, County Business Patterns, 1964
15,17	Water Use	"Economic Evaluation of Water", E.M. Lofting (Appendix B) U. of California Berkeley
30	Employment	U.S. Bureau of the Census, County Business Patterns, 1964.
	Water Use	1967, FPC Data
31,32 33,34	Water Use	"Economic Evaluation of Water" E.M. Lofting U. of California at Berkeley (Appendix B)
	Employment	U.S. Bureau of Census, U.S. Census of Business Retail Trade, 1963 Wholesale Trade 1963-County Business, 1964
35,36	Employment	U.S. Bureau of Census, Statistical Abstract of the United States
	Water Use	"Economic Evaluation of Water" E.M. Lofting U. of California at Berkeley (Appendix B)
5,7	Water Use	U.S. Bureau of Mines

SEQUENCE OF MODEL RUNS AND ANALYSIS

The development of the NAR estimates of future withdrawal levels was essentially an iterative process which closely reflected the ongoing nature of the planning effort. The demand model assimilates thousands of pieces of input data in arriving at projected values for water withdrawal. The initial development of the model and the adjustment of input information to eliminate inaccuracies can be thought of as the first step in developing the NAR estimates. The second step was to adjust the model in two ways. The first was for structural deficiencies which would not show up until some output became available to indicate the implications of some of the assumptions. The second type of adjustments, at this step, involved the utilization of information gathered at the various plan formulation meetings and feedback on preliminary estimates from the participating states and agencies. The third step was comprised of the development of the variant assumptions and the analysis of the results of these assumptions.

INITIAL DEVELOPMENT

The development of the model during step one revolved around the process of accumulating and employing the best available input information. At this stage, the Department of Agriculture information was incorporated into the model. The sequence of events during this stage is indicated in the following discussion.

The simplest set of input data was assembled first. This data set assumed that future technology and structural relationships were the same as in the mid 1960's base period. Only GNP, per capita income, population and population served were altered for the future benchmark years. Subsequent to this first set of simplified assumptions, assumptions were introduced which were felt to be better approximations of future conditions. Changes were made to take into account assumptions about the distribution of population among Sub-areas in the future; assumptions concerning the distribution of future employment among industries and Sub-areas based upon the Cornell University study were introduced; and assumptions concerning the distribution of fresh withdrawal between self-supply and public supply for the benchmark years were incorporated into the model.

Preliminary runs of the model were made at this stage. (These were the Base and National Efficiency runs.) Upon evaluation, it was discovered that changes in the model had to be made. For example, in certain Sub-areas where withdrawal was concentrated at one or two points, the per capita municipal withdrawal was felt to be much too low given the available information. The model was adjusted to replace the calculated per capita withdrawal wherever it fell below 50 gal/cap/day with the value 49.5 and to print out the statement that domestic use was less than 50 gal/cap/day.

The final adjustments in the first step were to test the impact of the Regional Development and Environmental Quality assumptions and to introduce assumptions concerning the future levels of water using technology.

ADJUSTMENT OF THE MODEL

The second step in the process was to adjust the input assumptions and, in some cases the model, to reflect information provided by the participating agencies and information gathered as a result of the plan formulation meetings.

The input assumptions adjusted, initially, were those dealing with withdrawal estimates for the agricultural, mineral and electric power generating sectors. Estimates of present and future withdrawal levels were provided by the Federal Power Commission, the Bureau of Mines and the Department of Agriculture. The projections were for the various benchmark years for each objective. The input data was adjusted so that the projected withdrawals were in agreement with the data provided by these agencies. In dealing with the Department of Agriculture's irrigation data, an error was discovered in the logic of the model. The net water sub-routine was double counting the portion of non-agricultural irrigation consumption which was publicly supplied. This called for a revision in the net water sub-routine in the model (see User's Manual for detailed description of the change).

The second set of adjustments were made on the basis of information provided through the plan formulation meetings. For example, information was received on the existence of withdrawal demands which were not reported in any of the previously available sources, often because of disclosure problems. Adjustments were also made to reflect the more detailed information available at the local level on Base year withdrawals (i.e., Susquehanna withdrawals and Delaware withdrawals were lowered to reflect surveys made of water use by industry in these basins).

Assumptions about rates of technological change for specific industries were also altered based upon discussions with industry and state agency representatives. The chemical industry representatives pointed out the rate of technological change initially assumed was much too low and after careful evaluation and discussion, changes in the future rate of technological change were made. The various changes were incorporated into the model over a period of time as there was a time lag in acquiring information from many different sources and in receiving and evaluating the feedback generated during the planning process.

At this point a final set of runs was made. They were final in the sense that they incorporated the best available information that the NAR Group could assemble. This resulted in the finalization of the Base run, and the:

1980)
2000) National Efficiency runs (2NE),
2020)

the

1980)
2000) Regional Development runs (2RD)
2020)

and the

1980)
2000) Environmental Quality runs (2EQ).
2020)

Run chronology is given in Table 1. The mid 1960 base period is termed BASE 1964 for the purpose of run designation in the model.

VARIANT RUNS

The final step in the procedure was the development of the variant assumptions. The variants were designed to test the sensitivity of the systems to changes in the basic input assumptions. Various assumptions were made concerning the rate of technological change. A second major grouping of variant adjustments were made for each objective (Regional Development, Environmental Quality and National Efficiency). These included altering rates of population growth, productivity assumptions, and number of man hours worked per year. The final set of variant assumptions were designed to test the implication of some outside constraint (i.e. legal) on the availability of water for specific industrial use. These assumptions were incorporated and the results evaluated at each stage.

TABLE 1

RUN CHRONOLOGY AND DESCRIPTION

Date	Run Name	Description
8/70	Base 1964 1980 1 NE	The 1980 1 NE deck was the 1964 deck with changes only in GNP, population, per capita income and population served. This assumes constant technology and structural relationships between industries.
8/70	1980 2 NE	This is the basic data deck with changes assumed in the distribution of population, employment, GNP, population and population served and the distribution of fresh withdrawal between self-supply and public supply. Changes in the sub-routine CONST were also discussed.
8/70	2000 1 NE 2020 1 NE	These were the Base 1964 decks with GNP, population, population served and per capita income adjusted to the 2000 and 2020 projections in Appendix B.
8/70	2000 2 NE 2020 2 NE Compare 2020 2 NE to Base 1964	These are the basic deck with projected changes in the distribution of employment, total population, population served and fresh withdrawal between public and self-supplied. Changes were also made for GNP, population, population served and per capita income based upon projected levels found in Appendix B.
9/70	1980 RG1 2000 RG1 2020 RG1	First variant run. Uses the 1NE decks - no distributional changes from Base year. Replaced GNP and per capita income on the assumption of increased productivity over the NE runs.
9/70	Base 1964 1980 1 NE 2000 1 NE 2020 1 NE 1980 2 NE 2000 2 NE 2020 2 NE 1980 2 RG1 2000 2 RG1 2020 2 RG1 1980 2 EQ 2000 2 EQ 2020 2 EQ Compare 1964 to 1980 1 NE Compare 1964 to 1980 2 NE	Runs were made for Plan Formulation meeting. Data on withdrawal from Federal Power Commission for sector 30 was converted into coefficients and replaced previously utilized water coefficient for that sector for the Base and 1 NE runs only.

Date	Run Name	Description
9/70	Base 1964 1980 1 NE 2000 1 NE 2020 1 NE 1980 2 NE 2000 2 NE 2020 2 NE 1980 2 RG1 2000 2 RG1 2020 2 RG1 1980 2 EQ 2000 2 EQ 2020 2 EQ	These runs were submitted with the 1964 water use coefficients throughout with the exception of sectors 1-3 and 30. These coefficients were projected on the basis of Dept. of Agriculture and FPC data. Agricultural inputs for irrigation (non-agricultural and agricultural) as well as agricultural water use other than for irrigation were provided by the Dept of Agriculture (AGIR, NAGIR, AGWS). The allocator of water use to the states (PSTATE) was adjusted for 1964 to bring us into line with historical data.
9/70	1980 1 NE 2000 1 NE 2020 1 NE 1980 2 NE 2000 2 NE 2020 2 NE 1980 2 RG1 2000 2 RG1 2020 2 RG1 1980 2 EQ 2000 2 EQ 2020 2 EQ	These runs incorporated the following changes: 1) Projected water coefficients for sectors 10-29 (industrial sectors) 2) Projected irrigation and agricultural water use other than irrigation information (AGIR, NAGIR, AGWS) 3) For 2 RG1 and 2 EQ runs coefficients for sector 30 - Power cooling - reflecting variant assumptions were used.
10/70	Base 1964 1980 2 EQ 2000 2 EQ 2020 2 EQ	Used to test for corrections in the net water subroutine. Particularly the allocation of consumption for INAG 37 (Non-Agricultural Irrigation) consumption was being double-counted.
11/70	1980 2 NE 2000 2 NE 2020 2 NE	Were re-run in order to test impact of changes in assumptions concerning rate of technological change. These changes were based upon best available information from industry groups, agencies. They were adopted. They specifically revolved around 6 major industrial water users.
12/70	1980 2 EQ 2000 2 EQ 2020 2 EQ 1980 2 RG1 2000 2 RG1 2020 2 RG1	Were re-runs reflecting assumptions used in NE runs made in 11/70 for rates of technological change.

Date	Run Name	Description
12/70	All Runs (Base 1964 and all Variants)	Re-runs were made on the basis of plan formulation feedback. Suggestions concerning the availability of fresh self-supply for future years were incorporated by altering the Municipal Supply adjustment factor (MSAF). It was felt that in certain areas maximum available self supply would be reached prior to 2020. The resulting increments to self supply for the years 2000-2020 were shifted to the public sector for these areas.
1/71	All Runs	The previous procedure of 12/70 was dropped because the shift of industrial self supply was reducing the regression equation estimates of public water needs below what was considered to be possible. The result was that these shifts of industrial water would be made prior to inputting the Demand Model data to the Supply Model.
3/71	1980 2 RG1 2000 2 RG1 2020 2 RG1 1980 2 EQ 2000 2 EQ 2020 2 EQ	Adjusted runs on the basis of new information provided by the Dept of Agriculture on the distribution of ground water between the assigned and unassigned category (OTIR,CROPIR).
6/71	Compare: 1980 2 NE to Base 1964 2000 2 NE to 1980 2 NE 2020 2 NE to 2000 2 NE Repeat this process for 2 EQ, 2 RG1 Compare to each other 2NE - 2 EQ 2 NE - 2 RG1, 2 RG1 - 2 EQ	These runs were done in order to get actual numerical results of the impact the various assumptions made for each variant had on the predicted water withdrawals.
6/71	2020 5 NE 2020 5 EQ 2020 5 RG1	The NE, EQ, 2 RG1 runs with an updated Regional Final Demand Distribution Vector based upon 1963 Data.

Date	Run Name	Description
6/71	2020 6 NE (Compare 2020 6 NE - 2020 2NE	This run assumes the same structural, distributional and technological situations as the 2 NE with a higher rate of productivity GNP and per capita income were changed.
6/71	2020 6 RD (Compare 2020 6 RD - 2020 2 RG1)	This run assumes the same structural, distributional and technological situations as 2 RG1 with an assumption that hours worked per year will be greater than in 2 RG1. GNP and per capita income were changed.
6/71	2020 6 EQ Compare 2020 6 EQ - 2020 EQ	This run assumes the same structural, distributional and technological situations as the 2 EQ run with the assumption of a lower productivity. GNP and per capita income were changed.
6/71	2020 7 NE Compare 2020 7 NE -2020 2 NE	This run is the basic 2020 2 NE run with the assumption of a slower rate of population growth. As a result GNP, per capita income, population and population served were changed.
6/71	2020 7 RD Compare 2020 7 RD -2020 2 RG1	This is the basic 2020 2 RG1 run with the assumption of a greater rate of growth of population. As a result GNP, per capita income, population and population served were changed.
6/71	2020 7 EQ Compare 2020 7 EQ -2020 2 EQ	This is the basic 2020 2 EQ run with the assumption that man hours per year are decreased. As a result GNP and per capita income were changed.
6/71	2020 8 NE Compare 2020 8 NE -2020 2 NE	This is the basic 2020 2 NE run with the additional assumption that technological change will reduce the water/$output requirement by 20 per cent. Sector 30 coefficients were changed.
6/71	2020 9 NE Compare 2020 9 NE -2020 2 NE	This is the basic 2020 2 NE run with the additional assumption that technological change will reduce water/$output requirement for the 6 major industrial users by 20 per cent. Sectors 10, 12, 16, 18, 19, 23 coefficients were reduced.

Date	Run Name	Description
6/71	2020 10 NE Compare 2020 10 NE - 2020 2 NE	This is the basic 2020 2 NE run with the assumption that for power and the 6 major users technology allows a 20 per cent reduction in water/$output requirements. Sectors 10, 12, 16, 18, 19, 23 and 30 coefficients were reduced.
6/71	2020 11 NE Compare 2020 11 NE - 2020 2 NE	This makes the same assumption as the 8 NE run except the percentage reduction is 50 per cent. Sector 30 coefficients were changed.
6/71	2020 12 NE Compare 2020 12 NE - 2020 2 NE	This makes the same assumptions as the 9 NE run except the percentage reduction is 50 per cent. Sectors 10, 12, 16, 18, 19, 23 coefficients were changed.
6/71	2020 13 NE Compare 2020 13 NE - 2020 2 NE	This makes some assumption as 10 NE run except that the percentage reduction is 50 per cent. Sectors 10, 12, 16, 18, 19, 23 and 30 coefficients were changed.
6/71	2000 14 NE Compare 2000 14 NE - 2000 2NE	This is the first of 6 policy runs. The run is a 2000 2 NE run with the assumption that for Sector 10, Food, etc., the water/$output requirements are reduced by 50 per cent by the year 2000. The reduction is above the assumed reduction due to technological change.
6/71	2000 15 NE Compare 2000 15 NE - 2000 2 NE	The description for the 14 NE run is accurate except the sector is Sector 12, Fabryarn.
6/71	2000 16 NE Compare 2000 16 NE - 2000 2 NE	The description for the 14 NE run is accurate except the sector is Sector 16, Paper Bx.
6/71	2000 17 NE Compare 2000 17 NE - 2000 2 NE	The description for the 14 NE run is accurate except the sector is Sector 18, Chemplst.
6/71	2000 18 NE Compare 2000 18 NE - 2000 2 NE	The description for the 14 NE run is accurate except that the sector is Sector 19, Petrl Ref.

Date	Run Name	Description
6/71	2000 19 NE Compare 2000 19 NE - 2000 2 NE	The description for the 14 NE run is accurate except that the sector is Sector 23, Prim Mfg.
10/71	1959 1 NE	This run is a test of the existing information in the model and its ability to predict backwards. The 1964 data were used with the following adjustments: 1. GNP, Per capita income 2. Proportion of GNP in the region 3. Water coefficients were adjusted to reflect the 1958 Census of Manufacturing data 4. Total populations 5. Population served
10/71	1954 1 NE	The run was made to test the information in the model and its ability to predict backwards. The 1959 data were used with the following adjustments: 1. GNP, Per capita income 2. Proportion of GNP in the region 3. Population 4. Population served 5. Water coefficients were adjusted to reflect 1954 Census of Manufactures data with the exception of Sectors 18, 19, 23 which were left unaltered due to problems with available census data.
1/72	1954 1 NE 1959 1 NE	These runs made one additional adjustment and were designed to be a test of the Lofting-Davis, Moore-Davis regionalization of I-O table methodology. The following data was adjusted on the basis of the 1958 I-O table: 1. Regional inverse coefficients (RICM) 2. Regional Final Demand Distribution Vector.

VARIANT RUN ANALYSIS

DESCRIPTION OF VARIANTS

The variant runs can be divided along two basic lines:

1) economic variants
2) technological variants

The development of the variants began with the Regional Development assumptions which were essentially economic in nature. More rapid rates of productivity increases were assumed, resulting in greater output and water use. The second foundation variant is the Environmental Quality variant which is a combination of economic assumptions about population growth, and rates of technological change, specifically in agriculture and power cooling. Technological change refers to changes in the need for water in the productive process. A technological variant would be one which alters the water use per dollar output relationship. The assumption is made that at worst, this water use per dollar output ratio remains constant in the future and, at best, the ratio will be reduced. If it is reduced, then we will say a technological change has occured.

Economic Variants

The economic variants involved several changes. One set of assumptions was concerned with the rate of population growth. Initially, population was assumed to grow at a slower rate than the basic assumption [National Efficiency conditions], then at a more rapid rate than this basic assumption. The impact of the same type of variation was examined for two additional variables:

(1) Productivity
(2) Man/hours worked per year

Technological Variants

The technological variants involved several sets of assumptions. Assumptions concerning the rate of technological change were made for:

(1) all industries
(2) individual industries
(3) various combinations of industries

Initially all industries rates of technological change were altered. Then the power cooling sector was considered separately. The six major industrial water users were then adjusted as a group

[Food and Kindred Products; Textiles; Paper and Allied Products; Chemicals and Plastics, Petroleum; and Primary Manufacturing]. Finally, both Power and the six major users were adjusted in combination with each other.

The second sub-set of technological variants consists of what have been termed policy variants. These assume that the rate of technological change [as reflected in the water per dollar output coefficients] which occurs in the six major industrial users is greatly accelerated by influence of factors outside the industry itself [ie. a legal restriction on the level of withdrawal or same form of public pressure to reduce water needs]. In testing the impact of this accelerated rate of technological change, each industry is considered separately.

SUMMARY OF RESULTS

Economic Variants

In summarizing the variants, the first set to be considered will be the economic variants. The first of these concern the assumptions about the rate of growth of population. The initial variant was to use National Efficiency assumptions except for a 1.0 percent rate of growth of population rather than a 1.3 percent rate. This would lead to a lower Gross Regional Product, in general lower per capita income, and as a result, a lower level of municipal withdrawal as well as industrial withdrawal. The magnitude of the charges are illustrated below for Area 8:

Run	Total Population	Per Capita Income ($)	Municipal Use (m.g.d.)	Total Fresh Withdrawal (m.g.d.)
2020 2NE	3,002,500	12,817	517	6,234
2020 7NE	2,558,400	10,992	432	5,530

A similar variation was made for a high rate of growth of population (1.6 percent as compared to 1.3 percent) and the Regional Development assumptions. The result for Area 19 is typical:

Run	Total Population	Per Capita Income ($)	Municipal Use (m.g.d.)	Total Fresh Withdrawal (m.g.d.)
2020 2RD	8,626,700	15,100	1,493	8,019
2020 7RD	11,376,000	13,027	1,784	8,742

The second variant, productivity followed the same type of procedure. A high productivity assumption (3.2 percent instead of

3.0 percent) and the remaining National Efficiency assumptions were made. The result for Area 14 is typical:

Run	Per Capita Income ($)	Municipal Withdrawal (m.g.d.)	Total Fresh Withdrawal (m.g.d.)	Fresh Consumption (m.g.d.)
2020 2NE	14,591	1,407	3,250	542
2020 6NE	14,984	1,418	3,450	580

and analogously, the low productivity assumption with all other Environmental Quality assumptions was made. For Area 21, this resulted in this type of change.

Run	Per Capita Income ($)	Municipal Withdrawal (m.g.d.)	Total Fresh Withdrawal (m.g.d.)	Fresh Consumption (m.g.d.)
2020 2EQ	11,802	429	3,138	1,154
2020 6EQ	9,285	418	2,929	1,127

The final set of economic variants dealt with the level of man/hours worked per year. The high rate of decline of man/hours per year assumption [a decline of 1549 instead of 1749] was used with the Environmental Quality assumptions. [a high rate of decline implies the lowest amount of hours worked by 2020]. The result for Area 6 is:

Run	Per Capita Income ($)	Municipal Withdrawal (m.g.d.)	Total Fresh Withdrawal (m.g.d.)	Fresh Consumption (m.g.d.)
2020 2EQ	10,316	119	475	156
2020 7EQ	9,544	116	449	153

The slow rate of decline of man/hours per year [1,949 by 2020 rather than 1,749] assumption was added to the standard set of Regional Developments assumptions and the resulting changes were of this magnitude for Area 13:

Run	Per Capita Income ($)	Municipal Withdrawal (m.g.d.)	Total Fresh Withdrawal (m.g.d.)	Fresh Consumption (m.g.d.)
2020 2RD	15,051	2,978	3,244	588
2020 6RD	18,022	3,148	3,437	623

Technological Variants

The second grouping of variants can be considered in two

sub-groups. The first is a series of assumptions dealing with the rate of technological change; the second is a set of assumptions designed to simulate the impact of decisions - other than economic or technological - on the levels of withdrawal needed to meet future output levels. The first sub-group can be divided into 8 sets of assumptions. They were:

(1) A minor acceleration in the rate of technological change for all industries in the NAR so that the gal. of water per dollar output requirement would be 20 percent less than the original National Efficiency assumptions for all industries.

(2) A rapid acceleration in the rate of technological change for all industries in the NAR so that the gal. of water/$ output would be 50 percent less than the original National Efficiency assumptions for all industries.

(3) A minor acceleration in technology in the Power industry - 20 percent below National Efficiency level of water (gals)/$ output requirements.

(4) A major acceleration in technology in the power industry - 50 percent below the National Efficiency water (gal)/$ output requirements.

(5) A minor acceleration in technology in the 6 largest industrial users [chemicals, petroleum, paper, textiles, primary manufacturing, food] - 20 percent below the National Efficiency level of water (gal)/$ output requirements.

(6) A major acceleration in technology in the 6 largest industrial users - 50 percent below the National Efficiency level of water (gal)/$ output requirements.

(7) A combination of both (3) and (5).

(8) A combination of both (4) and (6).

Examples of the resulting impact on the levels of fresh withdrawal are shown in Tables 1 through 3.

Variants in the second sub-group are what have been termed policy variants. These variants make the following assumption. The industrial water availability will be reduced by 50 percent compared to the National Efficiency level by the year 2000 for each of the 6 major industrial uses [food, apparel, paper, chemicals-plastics, petroleum and primary manufacturing.] This might be caused by institutional or legal considerations in the direct result of political action or public pressure. It provides a way

TABLE 1

REDUCTION DUE TO 20% INCREASE IN RATE OF TECHNOLOGICAL CHANGE

Industry	Area	Run		Self-Supplied (m.g.d.)	Publicly-Supplied (m.g.d.)	Consumption (m.g.d.)	% Change in Self-Supplied
Power	1	2020	2NE	2,504	8	454	
		2020	8NE	2,118	8	450	-15.4
Six Major Users	18	2020	2NE	1,988	397	1,015	
		2020	9NE	1,852	367	929	- 6.8
Power & Six Major Users	3	2020	2NE	2,120	14	61	
		2020	10NE	1,711	12	55	-19.3
All Industries	11	2020	2NE	6,044	42	196	
		2020	3NE	4,880	35	179	-19.5

TABLE 2

REDUCTION DUE TO 50% INCREASE IN RATE OF TECHNOLOGICAL CHANGE

Industry	Area	Run	Self-Supplied (m.g.d.)	Publicly-Supplied (m.g.d.)	Consumption (m.g.d.)	% Change in Self-Supplied
Power	21	2020 2NE	9,374	180	442	
		2020 11NE	5,728	180	368	-38.9
Six Major Users	20	2020 2NE	313	20	93	
		2020 12NE	263	16	87	-16.0
Power & Six Major Users	5	2020 2NE	853	16	65	
		2020 13NE	475	12	52	-44.3
All Industries	2	2020 2NE	2,096	30	80	
		2020 4NE	1,072	15	54	-48.9

TABLE 3

IMPACT OF REDUCTION OF 20 PERCENT IN TECHNOLOGICAL WATER WITHDRAWAL COEFFICIENTS FOR THE 6 MAJOR INDUSTRIAL USERS

	River Basin	Industrial[1] Fresh Self-Supply for Basic Run[2] (m.g.d.)	Change Due to Variant Assumption[3] (m.g.d.)	Percentage Change	Basin Fresh Water Self-Supplied for Basic Run (m.g.d.)	Change Due to Variant Assumption (m.g.d.)	Percentage Change
1	St. John	133	- 25	-18.79	2504	- 24	-0.95
2	Penobscot	703	- 138	-19.63	2096	- 138	-6.58
3	Kennebec	192	- 35	-18.22	2120	- 34	-1.60
4	Androscoggin	308	- 57	-18.50	868	- 54	-6.22
5	St. Croix - Coastal	302	- 55	-18.21	853	- 53	-6.21
6	Presumpscot - Saco	224	- 30	-13.39	922	- 29	-3.14
7	Merrimack	317	- 40	-12.61	1841	- 33	-1.79
8	Conn. R.	1426	- 120	- 8.41	6014	- 103	-1.71
9	Narragansett	753	- 93	-12.35	2108	- 65	-3.08
10	Thames - Housatonic	458	- 63	-13.75	3547	- 40	-1.12
11	St. L. Champlain	375	- 61	-16.26	6044	- 57	-0.94
12	Hudson R.	410	- 247	-60.24	7199	- 233	-3.23
13	NYC-Westch. Co.	110	- 3	- 2.72	2408	+ 13	+0.53
14	Passaic - Raritan	1089	- 146	-13.40	2805	- 114	-4.06
15	Delaware Bay	6835	-1212	-17.73	14390	-1119	-7.77
16	Coastal N.J.	38	- 2	- 5.26	696	- 1	-0.14
17	Susquehanna	2013	- 240	-11.92	19414	- 210	-1.08
18	Patuxent, Ches.	996	- 154	-15.46	1988	- 136	-6.84
19	Potomac	1406	- 180	-12.80	8052	- 167	-2.07
20	Rappahannock - York	132	- 22	-16.66	315	- 21	-6.66
21	James R.	1616	- 295	-18.25	9374	- 275	-2.93

(1) Includes NAR Sectors 4 through 29.
(2) Basic run is 2020 2NE.
(3) Variant run is 2020 9NE.

of testing the implications of various policies that may be erected. The resulting impact is felt most strongly at the area level.

Tables 4 through 6 provide examples of the impact of several of the variant assumptions on the future levels of fresh water withdrawal needs.

TESTING THE DEMAND MODEL: PROJECTIONS BACKWARD IN TIME

An additional type of variant run was made on the model to assist in evaluating the model's general usefulness as a projection device, and to aid in the adjustment of input information to improve specific aspects of the projection. In this type of run the model was used to project backwards in time to whether the estimates that it produced for earlier years, given appropriate input assumptions, approximated water withdrawals known to have taken place from census or other information.

For example, two relatively simple runs backward were made to compare the model's estimates of fresh water withdrawals in industry for the NAR with those given for an area approximate the NAR is the volume of Water Use in Manufacturing for 1959 and 1954 included in the Census of Manufactures. While many input assumptions can be modified to represent years earlier than the base year, for the two runs described the only changes in input information were the use of 1959 and 1954 GNP figures (The reuse coefficients SAIL, SAMIL and SAPCL were set to 1, indicating no recirculation or reuse). The estimates of the model for the NAR were compared with an area that approximates the NAR (but which excludes area 11 and includes parts of Virginia and North Carolina not in the NAR) for which the census data are readily available. For 1959, the model underestimated withdrawals for industry by 3.18%, for the area as a whole and for 1954 the model underestimated withdrawals by 9.38%. For smaller regions within the NAR to which comparisions with the census could be made, variations were larger. Additional runs backward, using more detailed attempts to adjust input information to approximate earlier-year conditions were also made.

Although personal success with projections backwards provides no guarantee of good performance for projections into the future, the rruns cited and other made gave a degree of general confidence in the model and gave also a substantial amount of insight into particular changes that might be made in input data to improve projections into the future.

TABLE 4

IMPACT OF REDUCTION OF 50 PERCENT IN TECHNOLOGICAL WATER WITHDRAWAL COEFFICIENTS FOR PAPER AND ALLIED PRODUCTS

	River Basin	Industrial(1) Fresh Self-Supply for Basic Run(2) (m.g.d.)	Change Due to Variant Assumption(3) (m.g.d.)	Percentage Change	Basin Fresh Water Self-Supplied for Basic Run (m.g.d.)	Change Due to Variant Assumption (m.g.d.)	Percentage Change
1	St. John	73	- 23	-31.5	321	- 23	- 7.
2	Penobscot	415	-195	-46.98	632	-193	-30.53
3	Kennebec	128	- 54	-42.18	343	- 53	-15.45
4	Androscoggin	213	- 77	-36.15	248	- 76	-30.64
5	St. Croix - Coastal	194	- 51	-26.28	235	- 50	-21.27
6	Presumpscot - Saco	135	- 38	-28.14	270	- 37	-13.70
7	Merrimack	200	- 25	-12.50	1047	- 23	-2.19
8	Conn. R.	843	-133	-15.77	3437	-125	-3.63
9	Narragansett	477	- 38	- 7.96	1522	- 35	-2.29
10	Thames - Housatonic	284	- 41	-14.43	2232	- 38	-1.70
11	St. L. Champlain	250	- 52	-20.80	2975	- 49	-1.64
12	Hudson R.	853	- 90	-10.55	5016	- 88	-1.75
13	NYC-Westch. Co.	58	0	0	2014	+ 2	+0.09
14	Passaic - Raritan	713	- 96	-13.46	2198	- 93	-4.23
15	Delaware Bay	3803	-139	- 3.65	9761	-133	-1.36
16	Coastal N.J.	26	0	0	505	0	0
17	Susquehanna	1165	-149	-12.78	12236	-148	-1.20
18	Patuxent, Ches.	586	- 9	- 1.53	1402	- 8	-0.57
19	Potomac	915	-116	-12.67	4938	-115	-2.32
20	Rappahannock - York	118	- 1	- 0.84	299	- 1	-0.33
21	James R.	1239	-188	-15.17	4612	-179	-3.88

(1) Includes NAR Sectors 4 through 29.
(2) Basic run is 2000 2NE.
(3) Variant run is 2000 16NE.

TABLE 5

IMPACT OF REDUCTION OF 50 PERCENT IN TECHNOLOGICAL WATER WITHDRAWAL COEFFICIENTS FOR CHEMICALS AND PLASTICS

	River Basin	Industrial(1) Fresh Self-Supply for Basic Run(2) (m.g.d.)	Change Due to Variant Assumption(3) (m.g.d.)	Percentage Change	Basin Fresh Water Self-Supplied for Basic Run (m.g.d.)	Change Due to Variant Assumption (m.g.d.)	Percentage Change
1	St. John	73	0	0	321	0	0
2	Penobscot	415	0	0	632	0	0
3	Kennebec	128	0	0	343	0	0
4	Androscoggin	213	- 12	- 5.63	248	- 12	- 4.83
5	St. Croix - Coastal	194	- 30	-15.46	235	- 29	-12.34
6	Presumpscot - Saco	135	- 2	- 1.48	270	- 2	- 0.74
7	Merrimack	200	- 22	-11.00	1047	- 16	- 1.52
8	Conn. R.	843	- 26	- 3.08	3437	- 13	- 0.37
9	Narragansett	477	- 68	-14.25	1522	- 49	- 3.21
10	Thames - Housatonic	284	- 20	- 7.04	2232	- 13	- 0.58
11	St. L. Champlain	250	- 3	- 1.20	2975	- 3	- 0.10
12	Hudson R.	853	- 74	- 8.67	5016	- 62	- 1.23
13	NYC-Westch. Co.	58	0	0	2014	+ 2	+ 0.09
14	Passaic - Raritan	713	- 94	-13.18	2198	- 78	- 3.54
15	Delaware Bay	3803	-183	- 4.81	9761	-124	- 1.27
16	Coastal N.J.	26	- 2	- 7.69	505	- 2	- 0.39
17	Susquehanna	1165	- 94	- 8.06	12236	- 88	- 0.71
18	Patuxent, Ches.	586	- 88	-15.01	1402	- 78	- 5.56
19	Potomac	915	-191	-20.87	4938	-187	- 3.78
20	Rappahannock - York	118	- 49	-41.52	299	- 47	-15.71
21	James R.	1239	-357	-28.81	4612	-336	- 7.28

(1) Includes NAR Sectors 4 through 29.
(2) Basic run is 2000 2NE.
(3) Variant run is 2000 17NE.

TABLE 6

IMPACT OF REDUCTION OF 50 PERCENT IN TECHNOLOGICAL WATER WITHDRAWAL COEFFICIENTS FOR PETROLEUM REFINING

	River Basin	Industrial[1] Fresh Self-Supply for Basic Run[2] (m.g.d.)	Change Due to Variant Assumption [3] (m.g.d.)	Percentage Change	Basin Fresh Water Self-Supplied for Basic Run (m.g.d.)	Change Due to Variant Assumption (m.g.d.)	Percentage Change
1	St. John	73	0	0	321	0	0
2	Penobscot	415	0	0	632	0	0
3	Kennebec	128	0	0	343	0	0
4	Androscoggin	213	0	0	248	0	0
5	St. Croix - Coastal	194	0	0	235	0	0
6	Presumpscot - Saco	135	0	0	270	0	0
7	Merrimack	200	- 1	- 0.50	1047	- 1	- 0.09
8	Conn. R.	843	0	0	3437	0	0
9	Narragansett	477	- 5	- 1.04	1522	- 3	- 0.19
10	Thames - Housatonic	284	0	0	2232	0	0
11	St. L. Champlain	250	0	0	2975	0	0
12	Hudson R.	853	- 1	- 0.11	5016	- 1	- 0.01
13	NYC-Westch. Co.	58	0	0	2014	0	0
14	Passaic - Raritan	713	- 7	- 0.98	2198	- 6	- 0.27
15	Delaware Bay	3803	-425	-11.17	9761	-406	- 4.15
16	Coastal N.J.	26	0	0	505	0	0
17	Susquehanna	1165	- 4	- 0.34	12236	- 4	- 0.03
18	Patuxent, Ches.	586	- 2	- 0.34	1402	- 2	- 0.14
19	Potomac	915	0	0	4938	0	0
20	Rappahannock - York	118	- 1	- 0.84	299	- 1	- 0.33
21	James R.	1239	- 2	- 0.16	4612	- 2	- 0.04

(1) Includes NAR Sectors 4 through 29.
(2) Basic run is 2000 2NE.
(3) Variant run is 2000 18NE.

CHAPTER 7

SUPPLY MODEL

INTRODUCTION TO THE SUPPLY MODEL

The supply model is a mathematical optimization model, whereas the demand model is a relatively simple simulation model that requires a great deal of fast arithmetic. The supply model solves a complicated system of mostly linear equations and constraints by means of a special computational IBM program (an MPS optimization system).

The supply model is somewhat complicated to use and thus is not so readily accesible to the agencies as the demand model. However, the MPS optimization system used in the supply model is widely used for linear programming and almost all agencies or private organizations should have access to universities or consulting groups who can give aid with this. In part the difficulties of using the model are inherent in the idea of keeping some intuitive grasp of the actions of large linear models.

Inpart, also, the difficulties arise because the NAR model has some cost curves that are shaped the "wrong way", that is, convex to the origin. Hence the model does not guarantee a global optimum; it thus should be used by experienced personnel who are able to perceive possibilities for gain in the model beyond local optima.

The steps involved in building and using the mathematical programming model were to identify the problem of concern, to model it in terms of algebraic equations, to find appropriate empirical information for the coefficients in the equations, and then to solve the problem by coding it for a pre-built mathematical programming routine and running it on the computer for which that program was developed.

The programming model utilizes a model of the hydrology of each of 50 sub-areas. The system can be depicted as a hopper, into which various sources of flow enter and various demands on the system exist, leaving a net return flow.

The supply model brings in not only the ability to incorporate assumptions that have to do with various objectives, but in addition to deal with certain aspects of uses in addition to those for which flow demands are projected. Instream flow constraints can be utilized in the model, and are in fact incorporated into the runs. These can be instream flow constraints for fish and wildlife, for pollution control, for recreation and for environmental quality and legal, thus bringing portions of these needs or demands into the information system, at least potentially and in part actually.

DESCRIPTION AND FORMULATION OF THE MODEL

The material that follows is excerpted from the NAR Special Publication 2, "A Supply Model for the North Atlantic Regional Water Resources Study" which includes a users manual for the supply model. The material presents a detailed description of the formulation of the supply model. It should be noted that the material also includes a description of the executive routine developed for supply model output. It is this output that has been used in plan formulation meetings and discussions, rather than the direct output from the MPS mathematical programming package. The executive routine was developed because the output from the MPS system itself is very difficult to read and interpret without special training; the output as transformed by the executive routing is readily accessible to all planners.

A SUPPLY MODEL FOR THE NORTH ATLANTIC REGIONAL WATER RESOURCES STUDY

PREPARED FOR

U.S. DEPARTMENT OF THE ARMY
CORPS OF ENGINEERS

BY

META SYSTEMS INC
CAMBRIDGE, MASSACHUSETTS

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Introduction

The North Atlantic Region (NAR) stretches from North Carolina to Maine and includes six major regions and the basins of twenty-one major rivers and fifty sub-basins, making up a total area of approximately 167,000 square miles. Figure I shows the region. In the context of the NAR framework planning effort, the Corps of Engineers initiated a systems analysis study of the region concerning both the regional demand and the regional supply of water in this area. The study reported herein is on the supply side of the systems analysis. It is a model of the supply of water in each of the fifty sub-basins, subject to meeting the demand in each of the sub-basins and minimizing the total cost of supply, but allowing for inter-basin transfers.

The purpose of the Meta Systems study was to develop a mathematical programming model for the NAR plan formulation, which would permit rapid evaluation of the sources and cost of the supplies of water required to meet various specified sub-area water requirements with an objective of minimizing the total cost of development. The basic data given for the model consists of withdrawal, in-stream and consumption requirements for the fifty NAR sub-areas and combinations thereof, data on existing supplies, yield from prospective upstream and major surface storage developments and groundwater sources, information on prospective intra- and inter-basin transfers, and data on associated costs of development. Provision is also made for inserting into the model and varying parametrically constraints on source, degree, and type of development to be used in each case.

The model is based upon utilizing existing programs written for mathematical programming with appropriately modified sub-routines for data management. This report presents the model developed; the associated computer programs and instructions for them are appended to the report.

The classification of water types in the model is compatible with the classification scheme of the NAR demand model. The model considers two qualities of water: (1) fresh water of class D or above and (2) waste water. In each sub-basin, there are assigned and unassigned water demands. In each case the assigned water is groundwater. This means that a certain portion of the groundwater storage developed in the sub-basin must be used for specified activities such as irrigation,

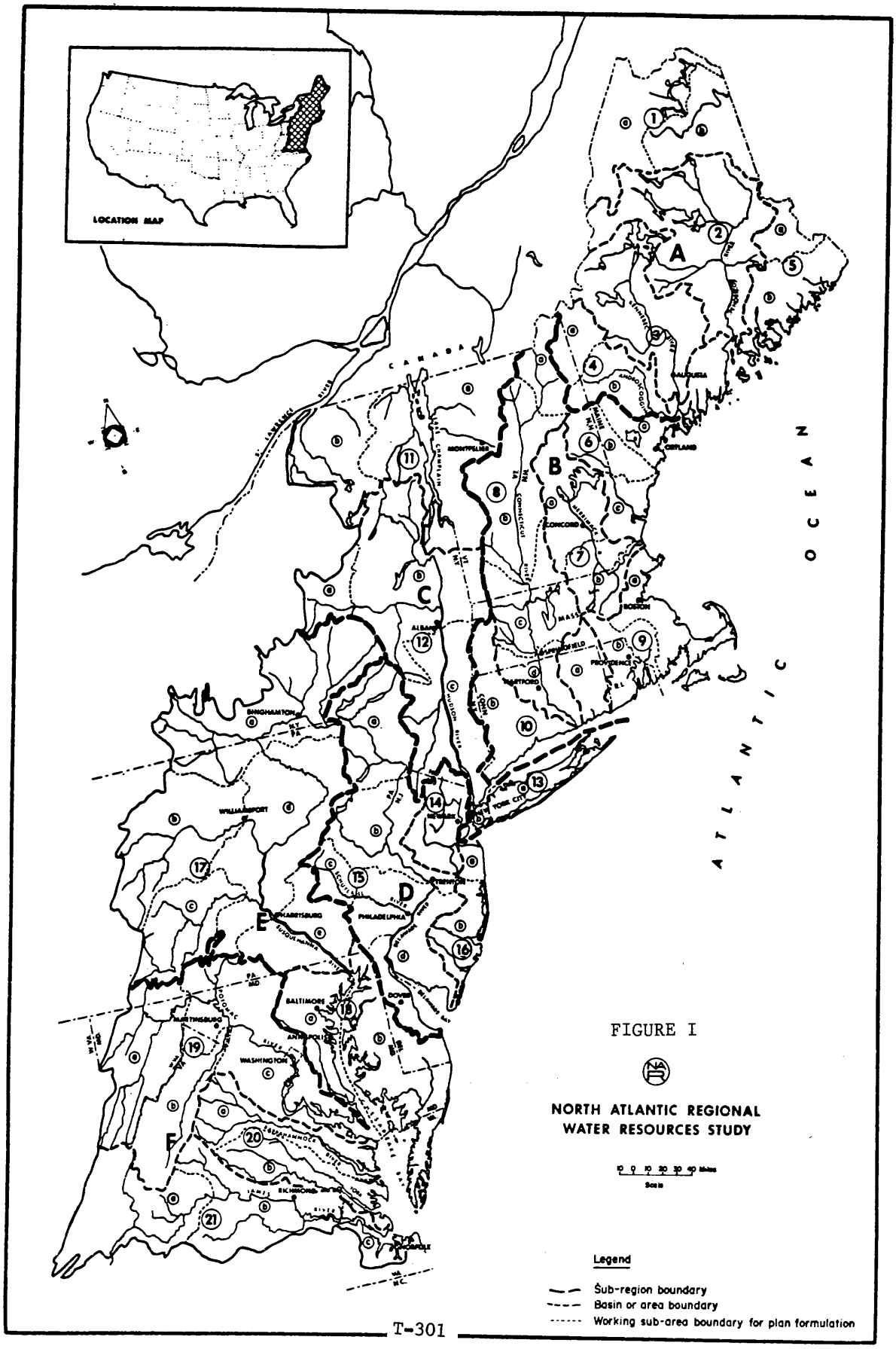


FIGURE I

NORTH ATLANTIC REGIONAL WATER RESOURCES STUDY

Scale

Legend

- Sub-region boundary
- Basin or area boundary
- Working sub-area boundary for plan formulation

municipal supply, and so forth. Figure II presents a schematic representation of the NAR region natural drainage connections and possible water transfers.

Model Formulation

In order to make a model of this complicated water resources system it is necessary to make several simplifying assumptions. The chief assumptions are as follows:

1. All of the water supplying and using activities in a sub-basin are considered to act at one point. Therefore, the NAR becomes a series of 50 nodes linked by natural drainage and man-made inter-basin transfers.

2. All yields from storages are based on critical period analysis. This allows us to use a static deterministic model.

3. Return flows from fresh water can be used to satisfy demands for waste water.

4. Inter-basin groundwater movements have been ignored.

The first assumption allows us to write generalized continuity relationships for each sub-basin. A typical sub-basin is indicated in Figure III. In this arrangement all of the main stream storage is lumped into one with a safe yield of s_i. The same holds true for upstream storage and groundwater storage. All of the water available for meeting the demand is shown entering a hopper (including desalted saline or brackish water) from where it is available to meet the demands or be used for export. The sub-basins are related to each other by continuity of the natural drainage systems, outflows and inflows, and the imports and the exports. A listing of variables and parameters is given in Table 1.

The model may be explained algebraically as follows:

Activities - Design Variables

U_i yield from upstream storage in i

S_i yield from mainstream storage in i

G_i yield from groundwater storage developed in i

G_{A_i} assigned yield from groundwater storage in i

FIG. II NAR REGION SCHEMATIC OF EXISTING AND POTENTIAL WATER TRANSFER NETWORK

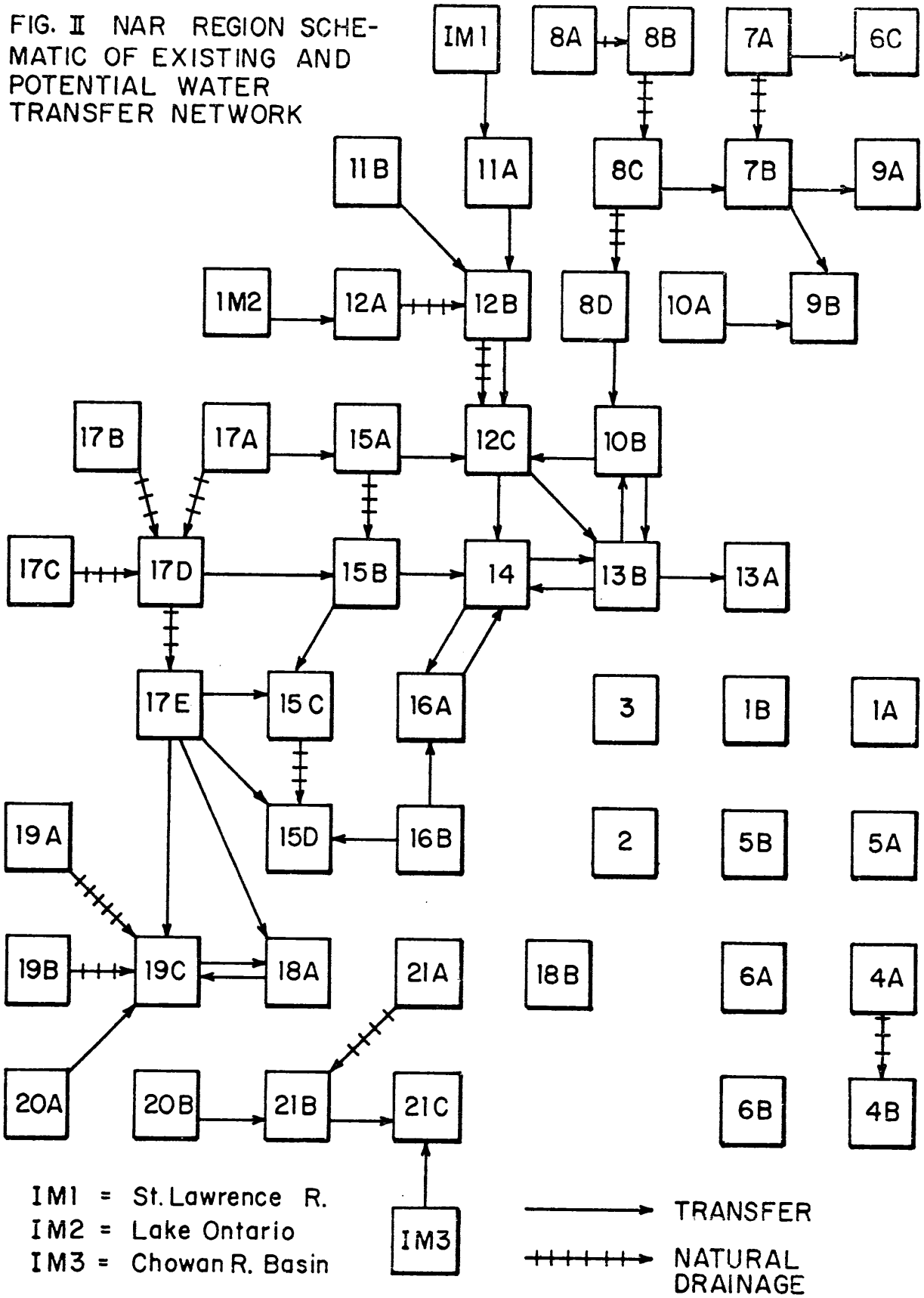
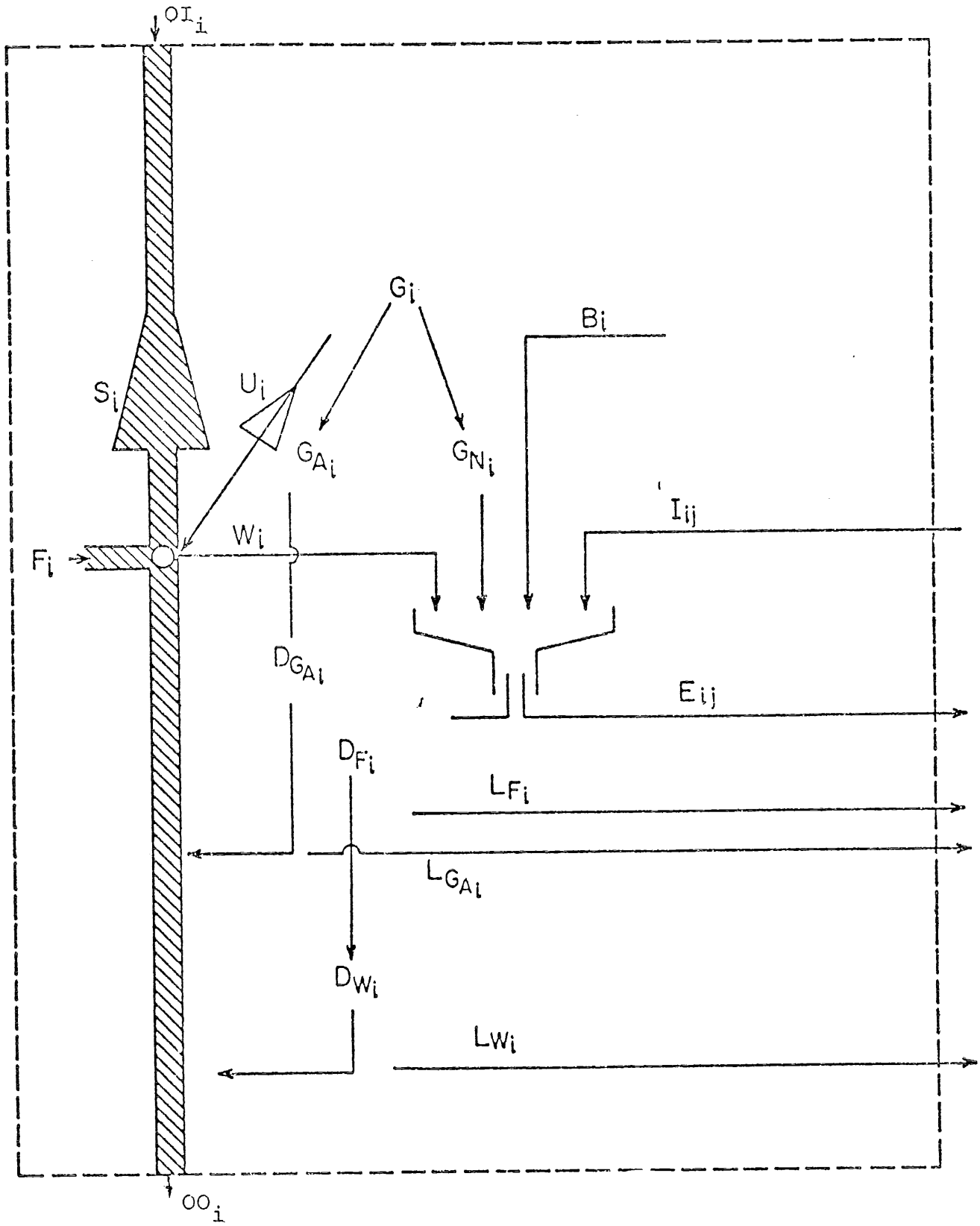


FIGURE III
TYPICAL SUB-BASIN i



G_{N_i} non-assigned yield from groundwater storage in i

B_i desalinated brackish or saline water used in i

W_i withdrawals from stream in i

E_{ij} export from i to j $j \varepsilon J_i$

I_{ij} import from j to i $j \varepsilon J_i'$

F_i intra-flow generated in i

Inter-basin natural outflow and inflow

OI_i total surface inflow into i

OO_i total surface outflow from i

Given Requirements (From the NAR Demand Model)

D_{F_i} demand for fresh water in i

D_{W_i} demand fro waste water in i

D_{G_i} total demand for assigned groundwater in i

L_{F_i} consumption of fresh water in i

L_{W_i} consumption of waste water in i

$L_{G_{Ai}}$ consumption of assigned groundwater in i

Constraints

(1) $\overline{U}_i$ upper limit of yield from upstream storage in i

(2) $\overline{S}_i$ upper limit of yield from mainstream storage in i

(3) $\overline{G}_i$ upper limit of yield from groundwater storage in i

(4) T_i upper limit of total basin hydrologic development in i

(5) OL_i low flow constraints downstream of i, $i \varepsilon I_k$

(6) Q_i low flow constraint within i

(7) continuity or mass balance at each sub-basin

(8) Demand constraints

(i) fresh water
(ii) waste water
(iii) assigned groundwater

(9) Equality of import-export pairs

(10) Upper limits on capacity of export and import and existing transportation systems

(11) Subtractive relationship between unassigned groundwater development and available intra-flow in the sub-basin, and upper limit on intra-flow availability

(12) $\overline{B}_i$ upper limit of desalted brackish or saline water in i

(13) Continuity on inter-basin flows

(i) natural transport
(ii) man-made transport

The above constraint sets are written algebraically below.

(1) $U_i \leq \overline{U}_i \qquad \forall_i$

(2) $S_i \leq \overline{S}_i \qquad \forall_i$

(3) (i) $G_{N_i} + G_{A_i} = G_i \qquad \forall_i$

(ii) $G_i \leq \overline{G}_i$

(4) $S_i + U_i + G_i \leq T_i \qquad \forall_i$

(5) $OO_i \geq OL_i \quad i \varepsilon I_k$

(6) $OI_i + F_i + S_i + U_i - W_i \geq Q_i \qquad \forall_i$

(7) Σ (inflows + flows generated in sub-basin) = Σ outflows

$$OI_i + F_i + G_i + U_i + S_i + B_i + \sum_{j \varepsilon J_i'} I_{ij} = OO_i \qquad \forall_i$$

$$+ \sum_{j \varepsilon J_i} E_{ij} + L_{F_i} + L_{W_i} + L_{G_{A_i}}$$

(8) (i) Demand for fresh water:

$$\sum_{j \varepsilon J_i'} I_{ij} + W_i + G_{N_i} + B_i + \geq D_{F_i} + \sum_{j \varepsilon J_i} E_{ij} \qquad \forall_i$$

(ii) Demand for waste water:

$$\sum_{j \varepsilon J_i'} I_{ij} + W_i + G_{N_i} + B_i - L_{F_i} \geq D_{W_i} + \sum_{j \varepsilon J_i} E_{ij} \qquad \forall_i$$

(iii) Demand for assigned groundwater:

$$G_{A_i} = D_{G_i}$$

(9)* $I_{ij} = E_{ji}$ $\qquad \forall\ i,j \varepsilon \lambda$

(10) (i) $E_{ij} \leq \overline{E}_{ij}$ $\qquad \forall_i$ and $j \varepsilon J_i$

and

(ii) $I_{ij} \leq \overline{I}_{ij}$ $\qquad \forall_i$ and $j \varepsilon J_i'$

(iii) $E_{ij} \geq EE_{ij}$ $\qquad \forall_i$ and $j \varepsilon K_i$

and

(iv) $I_{ij} \geq IE_{ij}$ $\qquad \forall_i$ and $j \varepsilon K_i'$

(11) (i) $F_i = \overline{F}_i - \alpha_i\ G_{N_i}$ $\qquad \forall_i$

(ii) $F_i \leq \overline{F}_i$

(12) $B_i \leq \overline{B}_i$

(13) (i) $\sum_{i \varepsilon M_i} OO_i = OI_{i+1}$ for each natural drainage

(ii) $\sum_i \sum_j E_{ij} = \sum_i \sum_j I_{ij}$ $\qquad k,j \varepsilon \lambda$

The constraint sets, with the exception of numbers 5 and 6, reflect physical relationships or resource limitations. Constraints 5 and 6 are included to incorporate other objectives. Constraint 5 is included to capture those legal/political requirements on downstream flow levels. Constraint 6 is an attempt, with the limitations of treating sub-basins as a node, to reflect possible quality/recreational objectives by operationally forcing flow "within the node" to be above a certain level.

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* Inclusion of both export and import variables is a redundancy which was not eliminated in order to facilitate manipulations of model output.

Objective Function

To minimize total annual costs of meeting constraints:

$z = \Sigma$ (import transportation costs + storage development costs and desalination costs)

$$= \sum_{j \varepsilon J_i'} \sum_i c_{ij} (I_{ij}) + \sum_i c_{S_i} (S_i) + c_{U_i} (U_i)$$
$$+ c_{G_{A_i}} (G_{A_i}) + c_{G_{N_i}} (G_{N_i}) + c_{B_i} (B_i)$$

The objective function is a sum of linear and non-linear cost functions; the nonlinear functions are often non-convex. The implications of these characteristics are discussed below. Figures IV-VII present a few examples of the actual cost curves. The upstream cost yield and assigned groundwater cost yield curves are linear; all the others are nonlinear and this is true for most of the sub-basins.

The cost curves and model parameters were developed by the Corps of Engineers and the other cooperating agencies involved in the NAR study. The curves needed are cost yield curves. Yield from storage is a function of the operating policy. For the purposes of this model, an operating policy was assumed and the relevant cost yield curve derived and used. Alternative functions can be readily incorporated in the model. The cost curves are a function of assumed interest rates and time horizons and risk levels. Varying these assumptions results in a new objective function to which the model is adaptable.

The minimum cost efficiency objective could be modified by including additional relevant costs or benefits associated with any of the model variables. An interesting possibility would be to let the demands vary with upper bounds equal to the presently fixed values derived from the demand model. In this case, benefits estimates, if available, can then be attached to these demand variables and included in the objective function.

The model in present form yields a great deal of information with respect to the demand and other constraints. In addition to producing the optimum set of supplies and costs thereof, the model solution produces information on the "shadow prices" or "costs" associated

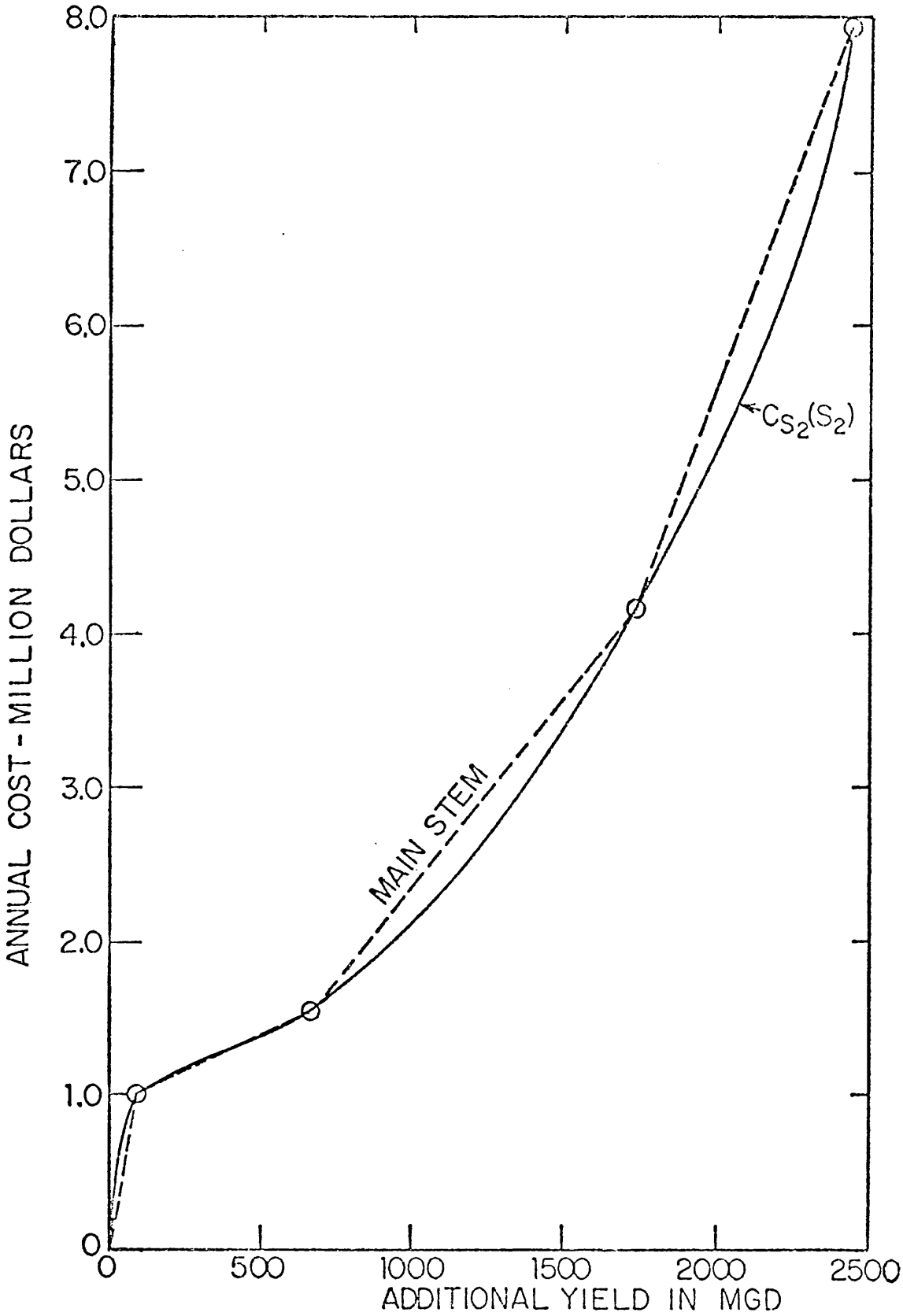
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
ANNUAL COST - MILLION DOLLARS
0
500
1000
1500
2000
2500
ADDITIONAL YIELD IN MGD
MAIN STEM
$C_{S_2}(S_2)$

FIGURE IV

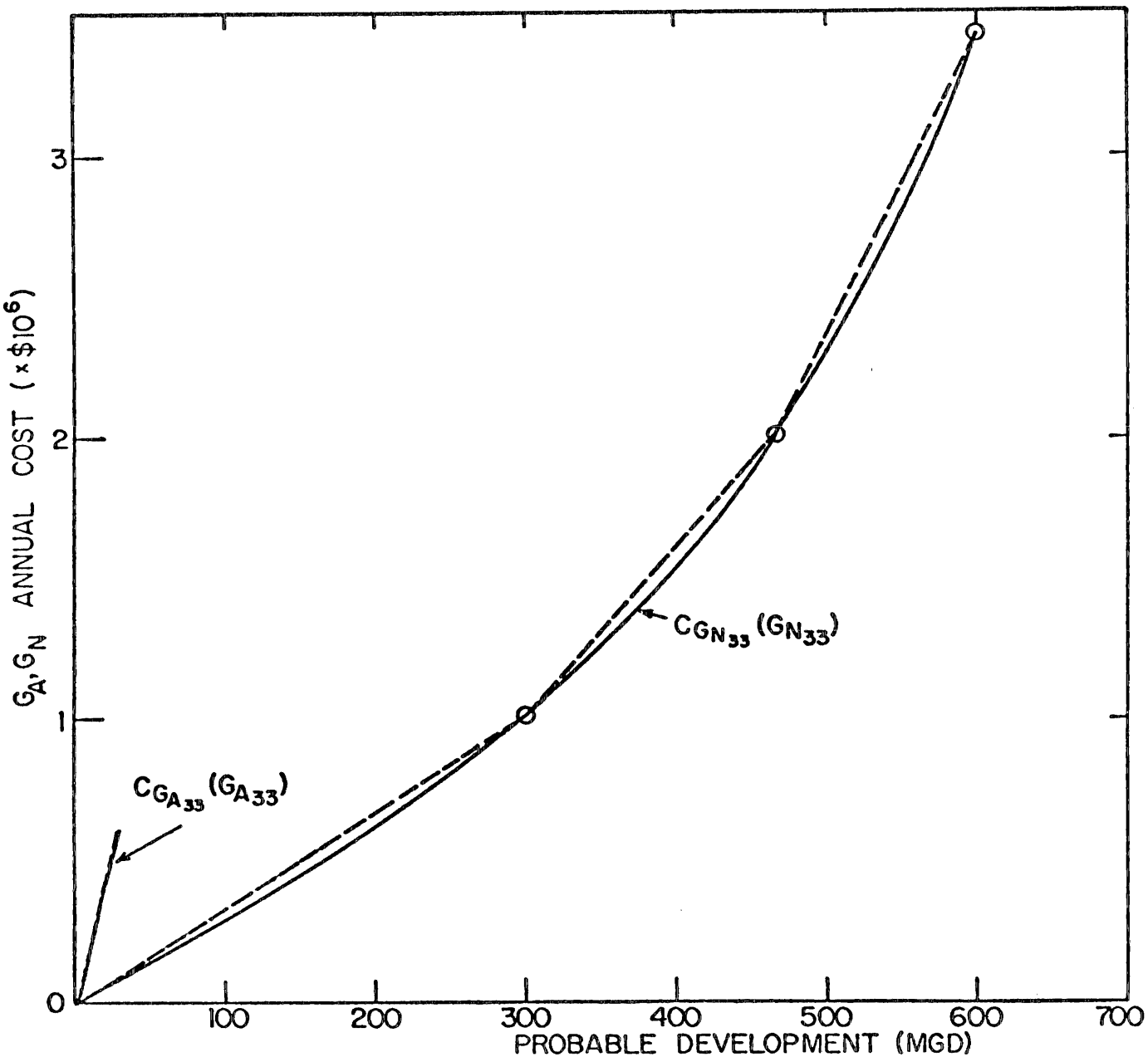
G_A, G_N ANNUAL COST (x 10^6)
0
1
2
3
100
200
300
400
500
600
700
PROBABLE DEVELOPMENT (MGD)
$C_{G_{A_{33}}}(G_{A_{33}})$
$C_{G_{N_{33}}}(G_{N_{33}})$

FIGURE V

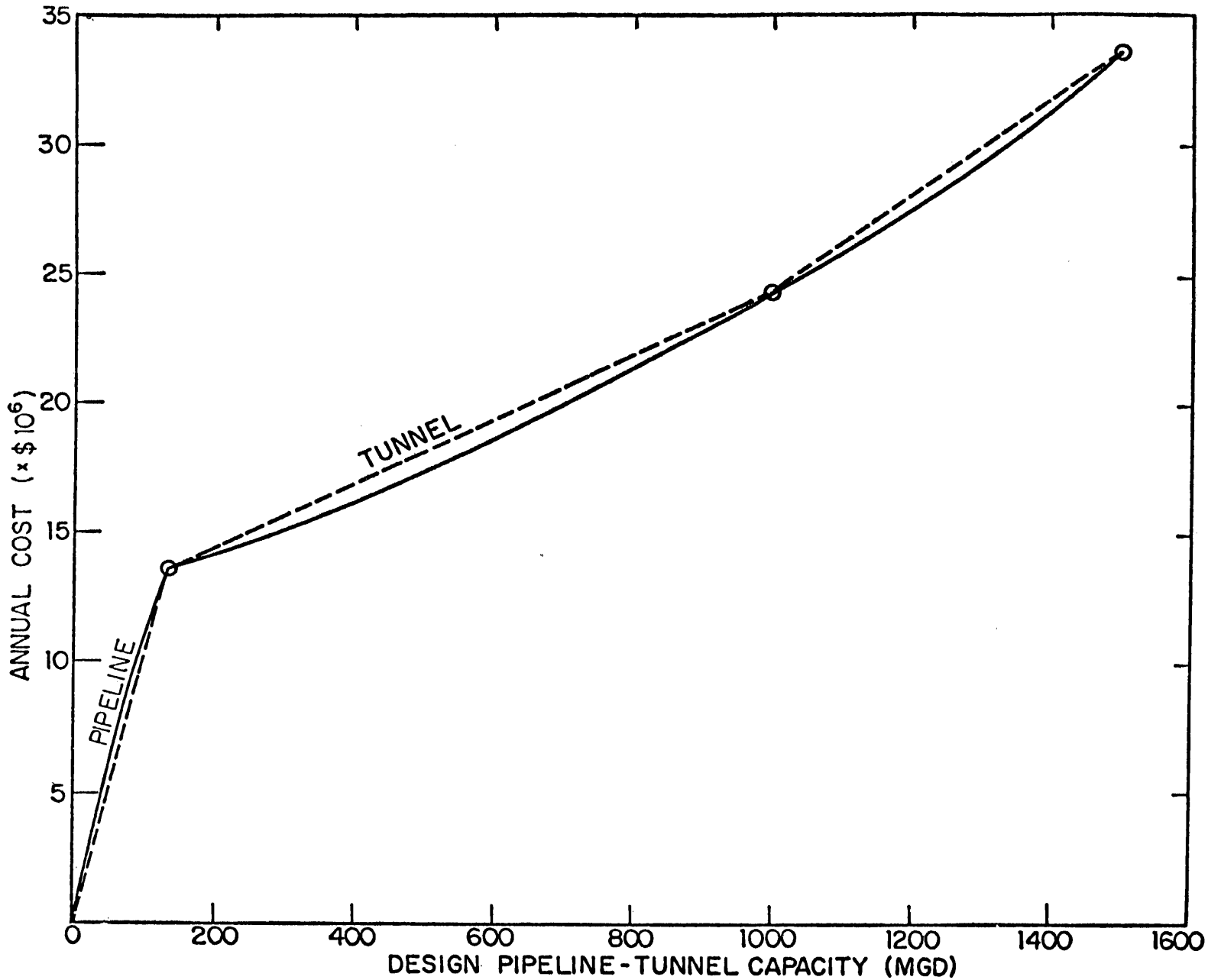
35
30
25
20
15
10
5
0
200
400
600
800
1000
1200
1400
1600
ANNUAL COST (x $10^6)
DESIGN PIPELINE-TUNNEL CAPACITY (MGD)
TUNNEL
PIPELINE

FIGURE VI

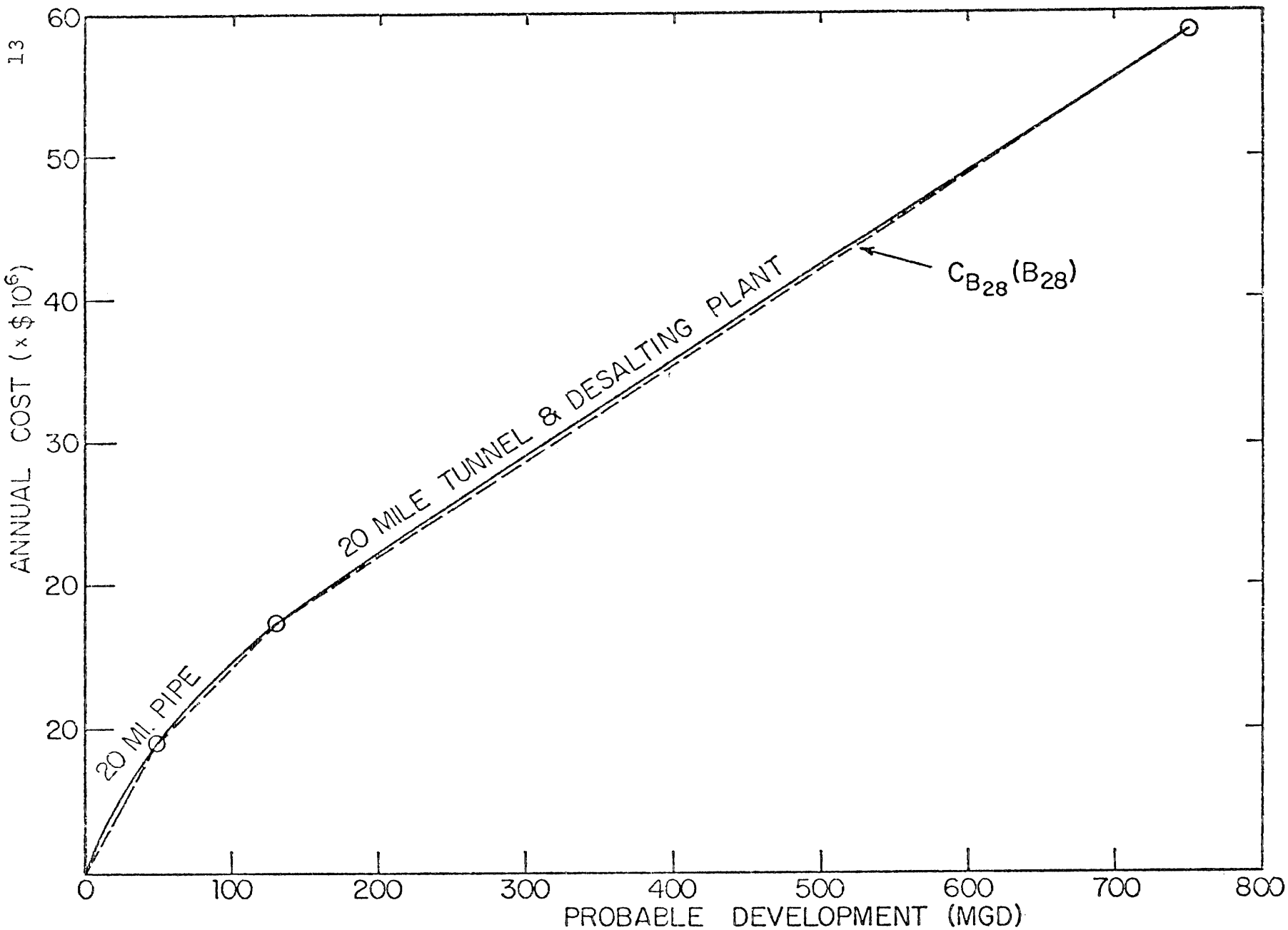

FIGURE VII

FIGURE VIIA

with binding constraints and bounds.* This information is contained in the dual activity and reduced cost output values of the MPS system output.**

These values are the rate of change of the objective function's value per unit of change in the associated right hand side of the constraint. For example, the appropriate dual value indicates how much the system costs (in annual terms) would decrease from a unit decrease in the fresh water demand in a binding sub-basin. Thus, by comparing the dual values of binding demand constraints for different constraints, the relative system costs of these demands can be examined.

Size of Problem Under Consideration

From Figure II we observe that the nature of the natural drainage and potential transportation link alleviates any immediate problem of decomposition significance. Thus, all 50 basins are considered as a system.

The transportation activities can be seen more clearly in Table II which shows the exporting and importing vector J_i and J_i' for each of the basins involved. Table III shows the existing transport vector as K_i and K_i'. Table IV lists the natural drainage system subsets. The problem size is observed in Table V.

Computational Aspects of the Problem

The resulting mathematical programming problem has a nonlinear objective function and all linear constraints and hence was programmed using a separable programming algorithm. The IBM MPS/360*** system was used, employing

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* For a thorough treatment of the theory of the dual problem including extensive discussions of the simplex multiplier (dual activity) see Dantzig, G.B., Linear Programming and Extensions, Princeton University Press, 1963.

** IBM Application Program, Mathematical Programming System/360 (360A-CO-14X) Linear and Separable Programming -- User's Manual, H20-0476-1.

*** Ibid, p.15.

the "delta"* form of the separable algorithm for approximating the nonlinear functions as piecewise linear functions. The piecewise linear approximations for the sample cost curves are shown in Figures IV through VII.

The resulting model, after inclusion of separable approximating variables and equations, has a matrix of over two thousand variables and one thousand rows. The version of the model currently running takes approximately thirteen minutes of CPU time to generate an initial feasible and optimal solution. Utilization of earlier solutions as starting points for problem variation reduces CPU time to three to five minutes.

As mentioned earlier some of the cost functions are non-convex in the feasible domain and an optimal solution generated may be a local optimum.** Examination of solutions for some base year demand configurations indicate global optimum since the solution values lie on the convex portion of the particular cost functions. When solutions are only locally optimal, a series of heuristics*** are being used to deal with this difficulty including multiple starts and selected use of bounds to identify additional local optimums.

The executive output routine whose program is discussed in the Appendix presents solution information broken down by sub-basin. The output format was designed such that information generated by the solutions could be readily available to planners without requiring a knowledge of the model's algebra or associated computer algorithm and codes. A sample of the output of one sub-basin is shown in Table VI.

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* Hadley, G., Nonlinear and Dynamic Programming, Addison-Wesley Company, 1964. Chapter 4.

** For a full discussion of this issue, see Hadley, Ibid.

*** For a discussion of formal approaches to other water resource problems with these characteristics, see Rogers, P., "Random Methods for Non-Convex Programming," Doctoral Dissertation, Harvard University, June 1966.

TABLE I

VARIABLES

B_i	Amount of desalinated saline or brackish waters imported to i.
E_{ij}	Export from i to j. mgd. For $j \varepsilon J_i$.
G_i	Amount of yield developed from groundwater in i. mgd.
G_{A_i}	Amount of assigned groundwater in i. mgd.
G_{N_i}	Amount of non-assigned groundwater in i. mgd.
I_{ij}	Import from j to i. mgd. For $j \varepsilon J_i'$.
$\overline{O}_i$	Total surface outflow from i. mgd.
$\underline{O}_i$	Total surface inflow into i. mgd.
S_i	Yield of mainstream storage in i. mgd.
U_i	Yield of upstream storage in i. mgd.
W_i	Withdrawals from stream in i. mgd.
F_i	Intra-flow available in i. mgd (Fresh water generated in i excluding yield of storage and groundwater)

PARAMETERS AND FUNCTIONS

c_{B_i}	Cost of importing desalinated brackish or saline water into i, annual costs per mgd import.
c_{ij}	Cost of transporting water from i to j expressed in terms of annual costs of capital, operation, maintenance and replacement per mgd water transported.
$c_{G_{A_i}}$	Cost of providing assigned groundwater yield in i in terms of annual costs per mgd of yield.
$c_{G_{N_i}}$	Cost of providing unassigned groundwater yield in i in terms of annual costs per mgd of yield.
c_{S_i}	Cost of providing yield of S_i in i. In terms of annual costs per mgd of firm yield.

TABLE I (cont'd)

PARAMETERS

c_{U_i}	Cost of providing yield of U_i in tributary storage in i. In terms of annual costs per mgd of firm yield.
D_{F_i}	Demand for fresh water in i. mgd.
D_{G_i}	Demand for assigned groundwater in i. mgd.
D_{W_i}	Demand for waste water in i. mgd.
$\bar{E}_{ij}$	Upper limit on export from i to j. mgd.
EE_{ij}	Lower limit on existing exports from i to j. mgd. For $j \varepsilon K_i$.
$\bar{F}_i$	Upper limit on intra-flow available in i mgd.
α_i	Parameter $0 \leq \alpha_i \leq 1$ a function of sub-basin geology reflecting the subtractive relationship of groundwater yield and intra-flow available.
$\bar{G}_i$	Upper limit on size of groundwater development in i. mgd.
i	Index on sub-basin numbers i = 1, . . . 50
$\bar{I}_{ij}$	Upper limit on import from j to i. mgd.
I_k	Subset of sub-basin indices in natural drainage system or river basin k.
IE_{ij}	Lower limit on existing imports from j to i. mgd. For $j \varepsilon K_i'$.
j	Index on sub-basin numbers j = 1, . . . 50.
J_i	Subset of sub-basins receiving export water from i.
J_i'	Subset of sub-basins exporting water to i.
M_i	Subset of sub-basins draining into i.

TABLE I (cont'd)

PARAMETERS

K_i	Subset of sub-basins having existing export facilities from i.
K_i'	Subset of sub-basins having existing import facilities to i.
$L_{G_{A_i}}$	Consumptive losses of assigned groundwater in i. mgd.
L_{F_i}	Consumption of fresh water in i. mgd.
OL_i	Low flow constraint downstream of i. mgd.
L_{W_i}	Consumption of waste water in i. mgd.
Q_i	Lower limit on instream flow in sub-basin i.
$\overline{S}_i$	Upper limit on mainstream storage in i. mgd.
T_i	Upper limit on sum of surface and groundwater yields.
$\overline{U}_i$	Upper limit on upstream storage in i. mgd.
$\overline{B}_i$	Upper limit on desalted brackish or saline water in i. mgd.
λ	Subset of import/export activities internal to the NAR region.

TABLE II

TRANSPORTATION ACTIVITIES*

Basin No. i		
6c	J_i'	(7a)
	J_i	(-)
7a	J_i'	(-)
	J_i	(6c)
9a	J_i'	(<u>7b</u>)
	J_i	(-)
9b	J_i'	(7b,10a)
	J_i	(-)
10a	J_i'	(-)
	J_i	(9b)
7b	J_i'	(<u>8c</u>)
	J_i	(<u>9a</u>, 9b)
8c	J_i'	(-)
	J_i	(<u>7b</u>, 12b)
8d	J_i'	(-)
	J_i	(10b)

* Underlining indicates an existing import or export.

TABLE II-2

Basin No. i		
10b	J_i'	(8d, 13b)
	J_i	(12c, 13b))
13a	J_i'	(13b)
	J_i	(-)
13b	J_i'	(10b, 12c, 14)
	J_i	(10b, 13a, 14)
11a	J_i'	(St. Lawrence)
	J_i	(12b)
11b	J_i'	(-)
	J_i	(12b)
12a	J_i'	(L. Ontario)
	J_i	(-)
12b	J_i'	(11a, 11b, 8c)
	J_i	(12c)
12c	J_i'	(12b, 15a, 10b)
	J_i	(14, 13b)
14	J_i'	(12c, 15b, 13b, 16a)
	J_i	(13b, 16a)

TABLE II-3

Basin No. i		
15a	J_i'	(17a)
	J_i	(12c)
15b	J_i'	(17d)
	J_i	(15c, 14)
15c	J_i'	(17e, 15b)
	J_i	(-)
15d	J_i'	(17e, 16b)
	J_i	(-)
16a	J_i'	(14, 16b)
	J_i	(14)
16b	J_i'	(-)
	J_i	(16a, 15d)
17a	J_i'	(-)
	J_i	(15a)
17d	J_i'	(-)
	J_i	(15b, 19c)

TABLE II-4

Basin No. i		
17e	J_i'	(-)
	J_i	(15c, 15d, 18a, 19c)
18a	J_i'	(17e, 19c)
	J_i	(19c)
19c	J_i'	(17e, 17d, 20a, 18a)
	J_i	(18a)
20a	J_i'	(-)
	J_i	(19c)
20b	J_i'	(-)
	J_i	(21b)
21b	J_i'	(20b)
	J_i	(21c)
21c	J'	(Chowan River, 21b)
	J	(-)

TABLE III

EXISTING TRANSPORT ACTIVITIES

Sub-basin number i	K_i'	K_i
9a	(7b)	(-)
7b	(8c)	(9a)
8c	(-)	(7b)
13b	(12c)	(-)
12b	(-)	(12c)
12c	(12b,15a)	(13b)
15a	(-)	(12c)
15d	(17e)	(-)
18a	(17e)	(-)

TABLE IV

NATURAL DRAINAGE SETS*

Basin No. i	
i = 4b	m_{4b} = (4a)
i = 7b	m_{7b} = (7a)
i = 8b	m_{8b} = (8a)
i = 8c	m_{8c} = (8b)
i = 8d	m_{8d} = (8c)
i = 12b	m_{12b} = (12a)
i = 12c	M_{12c} = (12b)
i = 15b	m_{15b} = (15a)
i = 15d	m_{15d} = (15b, 15c)
i = 17d	m_{17d} = (17a, 17b, 17c)
i = 17e	m_{17e} = (17d)
i = 19c	m_{19c} = (19a, 19b)
i = 21b	m_{21b} = (21a)

*Only those sets for sub-basins receiving flow from upstream are listed.

TABLE V

SIZE OF PROBLEM*

Activities		Number
Export activities	E_{ij}	37
Import activities	I_{ij}	40
Desalinated brackish and saline water import	B_i	18
Main storage	S_i	50
Groundwater storage	G_i	50
	G_{A_i}	50
	G_{N_i}	50
Upstream storage	U_i	50
Withdrawals	W_i	50
Return flows	R_i	50
Inflows	$\underline{O}_i$	13
Outflows	$\overline{O}_i$	50
		458 variables (or columns)

Constraints

Type	Number	Type	Number
1	50	10 i)	37
2	50	ii)	40
3 i)	50	iii)	7
ii)	50	iv)	8
4	50	11 i)	50
5	50?	ii)	50
6	50	12 i)	13
7	50	ii)	1
8 i)	50		206 constraints (or rows)
ii)	50		
iii)	50		
9	37		

*Without separable variables and constraints; with the addition of separable variables and constraints there are 991 variables and 994 constraints.

TABLE VI

BASIN 6C PRES SAC SUB-BASIN PISCATQA RUN YEAR 2000

SOURCES OF FLOW AND COST TO MEET FRESH WATER DEMAND 69 MGD,
WASTE WATER DEMAND 1 MGD, INSTREAM MINIMUM 82 MGD, AND
OUTFLOW MINIMUM 103 MGD.

SOURCE	FLOW (MGD)	ANNUAL COST ($MILLION 1970)
UPSTREAM STORAGE	34	0.20
MAINSTREAM STORAGE	0	0.0
GROUNDWATER ASSIGNED	12	0.32
GROUNDWATER UNASSIGNED	0	0.0
DESALTED WATER	0	0.0
EXISTING SUB-BASIN INTRAFLOW	105	0.0
SUB-TOTAL	151	0.52
IMPORT FROM SUB-BASIN MERRIMACK	0	0.0
NET TRANSFER	0	
TOTAL FLOW AVAILABLE	151	
CONSUMPTIVE LOSS	18	
SUB-BASIN OUTFLOW	133	

DEVELOPMENT OF SUPPLY MODEL INPUT DATA

DEMANDS

The requirements to be satisfied in each benchmark year were developed from the results of demand model runs. All supply model runs were mixed-objective runs. A simple auxiliary program was used to take the demand model outputs corresponding to the designated mixed objective in each Sub-area and prepare them on punched cards, as supply model input. Three categories of water are included in the input.

The demand for assigned ground water (DGA) is equal to the portion of agricultural water supply and irrigation pre-designated by input coefficients of the demand model.

The demand for other fresh water (DF) is equal to the sum of the net demands for public, self-supplied industrial, irrigation (unassigned portion) and agricultural (unassigned). It also includes consumption not counted in the net demands. In initial supply model runs power cooling demands were included but later runs included only power cooling consumption on the basis that this use would not occur in locations where water was not available under existing conditions or developed for other purposes under future conditions.

The demand for waste water (DW) is easily identified in the demand model output as it only occurs in the self-supplied industrial category on a separate line of the output printout.

In all cases, the irrigation demand from the demand model is divided by tow before incorporation in the supply model input. In the case of the assigned portion, this was an average felt to be realistic because of the seasonal requirement (demand model output represents maximum month) which is satisfied by a ground water supply based on annual yield. For the unassigned irrigation, this also appeared to be appropriate since only the existing resource would be affected according to the maximum month's demand. Satisfaction of this demand through reservoirs and ground water would involve equivalent annual drafts considerably less than the seasonal requirement.

COST FUNCTIONS

Cost functions for the development of supplies of additional water were necessary for major river storage, upstream storage, ground water, transfers between Sub-areas and desalting. These relationships were constructed in terms of net yield added and annual costs in 1970 dollars.

Storage and yield information for major river storage is summarized in Appendix E, together with the generalized cost curves used as the basis for cost-yield relationships. For each of the 41 Sub-areas with major river storage potential, a curve was developed of net yield versus costs from the practical development projects, assuming, generally, that the most efficient projects (in m.g.d./$) would be constructed first. As discussed.

in Appendix E, yield was usually determined at the projects except in a few Sub-areas where operation for a downstream location was assumed.

Data on storage and yield of upstream reservoirs contained in Appendix F and further discussed in Appendix E were supplemented by cost estimates for practical development storage prepared by the U.S. Department of Agriculture. For each of the 48 Sub-areas with upstream storage potential, a straight line relationship was assumed between net at-site yield and cost up to the point of practical development. The large number of sites distributed throughout the Sub-areas made it impractical to construct cost functions on a site-by-site basis, and the linear relationship appeared to be as realistic as any assumption for partial development within a Sub-area. For the purpose of the supply model analysis, exceptions were made in the upper limit of potential upstream storage development in Sub-area 9a and 14. In these two Sub-areas it was assumed that only one-half, or about 22 sites in 9a and 32 sites in 14, should be counted on because of the trends in urbanization and water supply sources.

Cost-yield relationships for ground water were based on yield and cost information contained in Appendix D. Over-all, the scale of development limit for which costs were estimated for supply model use was about 65% of full practical development. In each Sub-area, curves were constructed for both types of ground water delineated in Appendix D, municipal and industrial and rural irrigation. The latter was assumed to be available to meet the demand model assigned groundwater demand and the M&I ground water was considered available for unassigned demand as well as any assigned supply unfulfilled by existing assigned ground water supply. The cost-yield relationship for the assigned supply was linear, based on cost per m.g.d. for the particular aquifers in a Sub-area. The cost-yield relationship for the unassigned supply component is curvilinear, with increasing cost per m.g.d. reflecting less favorable aquifers and larger distances to probable points of use in each Sub-area.

Cost functions for inter-basin transfer of water were based on the generalized cost curves for tunnel and pipeline costs presented in Appendix E, estimated distances between assumed points of origin and use, and upper transfer limits large enough to provide water supply to the more critical Sub-areas under most conditions even if constraints were imposed regarding availability of one or more sources.

Cost-yield functions for desalting were derived from basic information supplied bythe Office of Saline Water. Desalting is assumed to occur in conjuction with multi-unit nuclear power stations as a supplemental source during shortage periods and upper limits are based on FPC projections. Potential costs are influenced significantly by plant load factors which reflect the percentage of total time a plant would be in use. For this study, load factors were assumed for each coastal area, and varied from 10 to 80% depending on the nature of the Area's supply. Highest factors were assumed in areas likely to have highly regulated or limited sources of conventional supply. The majorityof coastal Sub-areas were assigned load factors of 20-30%.

Cost of yield curves was drawn for each coastal Sub-area based on the generalized desalting cost relationships presented in Appendix E and the prospective nuclear power installation (desalting capacity assumed to be 1/5 the power generation capacity in megawatts). Costs of land and transfer facilities to an assumed location of probable need were included.

CONSTRAINTS AND PARAMETERS

Supply parameters required in the model input are generally self-explanatory. The upper limits of upstream, major river and ground water development, $\overline{U}$, $\overline{S}$, $\overline{G}_A$, and $\overline{G}_N$, correspond to the limits of the appropriate cost-yield functions. This is also true for the upper limit of desalting ($\overline{B}$) and transfer ($\overline{E}$ or $\overline{I}$).

The existing intraflow ($\overline{F}$) in a Sub-area represents resource currently developed under criteria covered in Appendix C and further discussed in Appendix E. These values are essentially the minimum flows derived from existing monthly flows having 0.01 shortage index, and correspond approximately to 7 day - 50 year values. The values include the yield of existing reservoirs within a Sub-area. Yields from major reservoirs have been calculated separately for a shortage index of 0.01 and are included even if the output is diverted to another basin. (One of the first steps in the model analysis is to account for this by satisfying existing diversions.) Tocks Island, Beltzville, Raystown and Gathright Projects have been assumed in operation under existing conditions.

The instream constraint values ("Q", or sometimes termed "C") provide a means of specifying how much water is to be left in the stream between the assumed points of withdrawal and return. It should be noted that it was necessary to treat Sub-area withdrawal as if it occurred at one point. Another function of the "Q" value is to prevent withdrawal use of any portion of the existing resource that is not considered to be available to satisfy these demands, primarily due to location.

The starting point for establishing "C" values was a determination of the portion of area in each Sub-area in which the existing resource was not usable because of the apparent location of demands. The portions of unusable area varied from 0 to 50%, with 34 of the Sub-areas falling in the 0% category. Next, an approximation of the portion of the usable area in each Sub-area that was upstream of an assumed point location of demands was made. In percentage, these values varied from about 50 to 80. For the reduced usable areas thus described, minimum flows of 0.2 csm in Sub-regions A through D and 0.1 csm in Sub-regions E and F were then added to the unusable existing minimum flow in each Sub-area. These flow criteria were adopted on the basis of the minimum flow analyses in Appendix C. The sums were the tentative "Q" values.

The tentative "Q's" were then compared with the implied "Q's" as determined from the base run (1965) of the model and existing conditions. The smaller of the two values in each Sub-area was adopted as "Q". This control by the use of the implied "Q's" was necessary to prevent unrealistic situations from developing in some Sub-area was adopted as "Q". This control by the use of the implied "Q's" was necessary to prevent unrealistic situations from developing in some Sub-areas where deficiences would occur under base year conditions due to assumptions made regarding single point withdrawal, reuse factors, etc.

The only exceptions to the adopted "Q" values were in Sub-areas 7b and 12c where substantial main river diversions which would not be returned to the originating areas were indicated in the future by supply model runs. Since these rivers would be highly regulated to provide the diversions, maintenance of adopted "Q's" could apply for rather long minimum flow durations. Accordingly, "Q's" were raised in these instances to values corresponding approximately to minimum monthly flows.

The "L.O." or outflow constraints provide a means of specifying the minimum outflow to be maintained at the outlet of each Sub-area. The Sub-area "L.O.'s" were set at 0.2 csm in Sub-regions A through D and 0.1 csm in Sub-region E and F, or the existing outflow, whichever was smaller. Exceptions were made at the outlet of Sub-area 12b where the existing outflow, which was somewhat greater than 0.2 csm, was retained for the purposes of maintaining the position of the salt fron; at the outlet of Sub-area 15a (montague, N.J.) where 1,750 cfs was specified in accordance with the Supreme Court decree; and at the outlet of Sub-area 15b (vic. Trenton, N.J.) where 3,000 cfs was considered desirable in accordance with DRBC programs.

The parameter reflects the subtractive relationship between ground water and intraflow in each Sub-area, or the portion of the unassigned ground water development that would be non-additive to the total resource. For the larger in Sub-areas having aquifers close to streams, with high permeability and good hydraulic connection, most of the pumped water would be derived from the streams and intraflow would be reduced almost by the amount of GN (see constraint 11 in "Description and formulation of the Model"). In accordance with discussions in Appendix E, composite factors expressing the ground-surface relationship were developed for each Sub-area on the basis of the type of water-bearing deposits. The subtractive values ( ) varied from 0 to 0.95 for the 50 Sub-areas.

The upper limit of yield from surface and ground sources (T) is a constraint on the total yield that can be developed in a Sub-area and is less than the sum of individual source yields due to an allowance for overlap between major river and upstream storage development (see Appendix E), the fact that GN is limited, in a few Sub-areas, by F/)this is necessary to prevent a negative F, equation 11 and a reduction in GA to the supply actually utilized in the last target year, 2020 (by definition this source is not available for other than assigned use).

SEQUENCE OF MODEL RUNS AND ANALYSIS

Three basic sets of data must be submitted in order that the optimized cost solution of the NAR Water Supply model may be derived (Fig 1). Computer modeling allows the manipulation and combination of many sets of data for different objectives. The actual use of the Linear Programing System also forces a more concise evaluation of the data requirement with greater degrees of refinement, resulting in more succinct thinking.

Thus the computer is used not only for its ultimate purpose as a planning tool but also as a means of improving the preliminary rational and reasoning in the formulation of objectives, data inputs and the degree of data precision. The sequence of Supply Model runs and the differences in data inputs reflect the improvement in the reasoning and illustrates the dynamism of user models in the planning process.

Generally speaking the hydrologic data inputs on development of the various water sources such as assigned groundwater (G_A), upstream storage (U), desalting (B), etc., as well as the river constraints of instream flow minimum (Q) and outflow minimum (L.O.) provided the initial basic core of data. Freshwater demands for the various specialized uses were extracted directly from the NAR Demand Model. These were converted to assigned groundwater, other fresh water and waste water demands and losses. The available water supply data set (I) was then matched with the water demand data set (III). The allocation of resource by basin ultimately was controlled by interbasin water transfer potential and cost of development.

The first few water demand data sets strained the capability of water supply systems because of the large demands of power cooling water. This led to the first series of readjustments of various hydrologic basin constraints and limits of development involving greater research and more refined data.

SERIES I (Run C)

a. Power cooling withdrawal demand

b. No instream minimums

c. No bounds on development or transfers

A significant factor in this run was the absence of instream minimum or the quantity of water that must remain in the river to insure minimum flows for fish and wildlife, water quality, etc. There were no bounds placed on transfers other than the presently existing quantities. Development within a Sub-area was unrestricted in the sense that the least cost solution was the ultimate goal. This occasionally resulted in major river development in some benchmark years which disappeared in a subsequent benchmark year because it was less expensive to import water or develop it in an upstream Sub-area.

WATER SUPPLY MODEL

Three Basic Data Sets

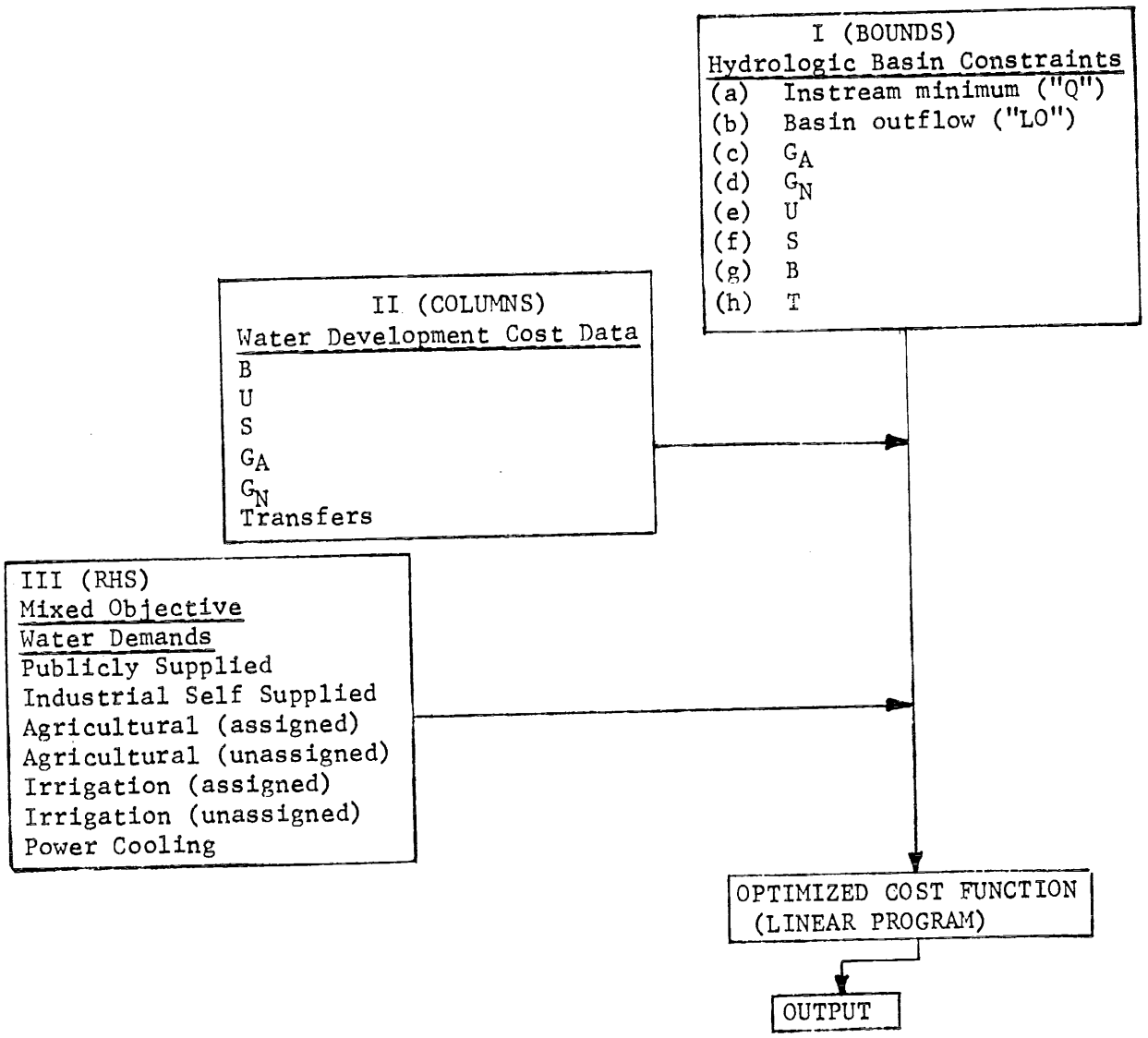

Figure 1

This series showed basin development to be less than expected. Also, some of the interbasin transfers were unreasonable. The patterns of U and S development within the hydrologic basins were erratic. This led to a basic decision to include instream minimum values. By inspection, some withdrawals left little or no water in the river at the modal point, although most was returned further downstream. Some cost curves were examined, particularly for water transfers, including reassessment of transfers points.

Some of the key interbasin transfers, and their magnitudes were generally expected, for example:

7B	to 9A,	approx.	1000 mgd in 2020
12C	to 13B,	"	2000 mgd in 2020
17E	to 18A,	"	650 mgd in 2020
8C	to 7B	"	500 mgd in 2020

Other transfers were either not foreseen or their magnitudes were not.

15A	to 12C	remained at 540 mgd throughout
15B	to 14	" at 65 mgd throughout
12C	to 14	800 mgd in 2020
8D	to 10b	400 mgd in 2020
7B	to 9B	400 mgd in 2020

SERIES II (Run D)

a. Power cooling withdrawal still included

b. Instream minimum values ("Q") included

Inclusion of instream minimum values, whereby a minimum quantity of water must remain in the stream at the assumed point of withdrawal, put a greater stress on the total water supply system. Additional water had to be developed for this new parameter. The low flow constraint downstream was not the limiting parameter in most of the basins, since after withdrawal and consumptive subtraction, most of the water was returned to the stream, thus meeting the Sub-area outflow constraint.

Key transfers were as follows:

7B	to 9A	increased to 1200 mgd by 2020
8C	to 7B	remained at 500
12	to 13B	increased to 2100
15A	to 12C	remained at 540 throughout
15B	to 14	increased to 560 in 2000 and dropped back to 65 in 2020
8D	to 10B	decreased to 260 in 2020
12C	to 14	increased to 900 in 2020
17E	to 15C	an aberrant 650 mgd in 2000, disappearing in 2020
19C	to 18A	120 mgd in 2000, disappearing in 2020

The Regional annual costs increased by about 25% over Series I.

SERIES III (NOPC)

a. Power cooling withdrawal no longer included (except consumption)

b. Instream minimum values included

The rationale for not considering power cooling fresh water withdrawal was that few projects are designed or built to provide water specifically for cooling purposes. Plants are sited where water is available. In Sub-areas where projected power cooling demands are greater than the other demands there was a large difference in storage. This was particularly true in Sub-areas 1B, 17B, 17C, 19A and 15C. Projected power cooling consumptive loss was still included in the total water supply picture, however.

Most of the transfers remained the same, with the exception of the aberrantly appearing transfers of 17A to 15A, 17E to 15C, 16B to 15D, and 13B to 14, now disappearing, presumably because of reduced power cooling demand.

The Regional annual cost decreased by about 10% over Series II costs.

SERIES IV (REALRUN)

A succession of trial analyses followed, resulting in a better comprehension of the sensitivy of the Supply Model and the parameters and variables which create a stress or tension on the system. Basins which were obviously in tension (Delaware, Potomac, Hudson, Merrimack, Passaic, Housatonic) were examined closely, reevaluating development limits for all sources of water, water transfer costs and distances and assumed operating policy for the water resource development within the basin.

It was decided to set lower limits of upstream storage development for expected municipal and irrigation uses. Also, lower limits of development within a Sub-area were incorporated whereby once a particular type of development occurred, the level of development would not be less during succeeding benchmark years. Only unassigned groundwater was allowed to vary since its project life was in the order of a planning period of 20 years.

By the end of these runs, only a transfer of 400 mgd from 17A to 15A was unanticipated. The total storage figures rose significantly because of additional restrictions on instream withdrawals, particularly when water was being exported, and constraints on storage development and interbasin transfer sequences which tended to be less efficient but were more logical. Development of water sources was at a slightly higher level than the total development with power cooling withdrawal.

The last runs of this series served as a basis for final review and discussion by the Plan Formulation Work Group. Their analysis led to certain changes resulting in the final computer run called Series V.

SERIES V

Basic changes in this series were limits on the maximum interbasin transfer from 15B to 14 (400 mgd) and the minimum transfer from 17E to 15D (62 mgd). In addition, development of the Adirondack region in 12B was constrained, decreasing storage availability and increasing costs somewhat. Storage development was reduced in Area 17, as for delivery of water at the outlet, since much of it was being exported to 18A. Similar operation was assumed for major river storage in Sub-area 15b since needs were predominately downstream of Trenton, N.J. This was primarily responsible for the elimination of the 400 mgd transfer from 17A to 15A in 2020.

Table 1 summarizes major and upstream storage development for the five series.

TABLE I

TOTAL STORAGE DEVELOPMENT

2020

	U(mgd)	U(Ac-ft)	S(mgd)	S(Ac-ft)
Series I	1,758	(2,200,000)	7,131	(3,400,000)
Series II	3,902	(4,200,000)	9,277	(5,200,000)
Series III	3,400	n.a.	8,252	n.a.
Series IV	4,000	(3,968,000)	9,570	(5,246,000)
Series V	3,799	(3,789,000)	8,908	(3,994,000)