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PUERTO RICO WATER RESOURCES PLANNING MODEL PROGRAM DESCRIPTION

by

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ABSTRACT

Because the use of the Mathematical Programming System -- Extended (MPSX) to solve large linear and mixed integer programs requires the preparation of many input data cards, a matrix generator program to produce the MPSX input data from a much more limited set of data may expedite the use of the mixed integer programming optimization technique.

The Model Definition and Control Program (MODCOP) is intended to assist a planner in preparing MPSX input data for the Puerto Rico Water Resources Planning Model. The model utilizes a mixed-integer mathematical program to identify a minimum present cost set of water resources projects (diversions, reservoirs, ground-water fields, desalinization plants, water treatment plants, and inter-basin transfers of water) which will meet a set of future water demands and to determine their sequence of construction. While MODCOP was specifically written to generate MPSX input data for the planning model described in this report, the program can be easily modified to reflect changes in the model's mathematical structure.

INTRODUCTION

The purpose of the model definition and control program (MODCOP) is to assist the planner in preparing input data to the Mathematical Programming System -- Extended (MPSX). Because of the large number of constraints (rows) and variables (columns) associated with some optimization models, such as the Puerto Rico Water Resources Planning Model described below, the use of a matrix generator to produce MPSX input data from a much more limited set of data may expedite the solution of a given problem. While every attempt has been made to keep MODCOP flexible, it is primarily designed to produce a specific problem matrix. By making minor changes to MODCOP and the input data, the planner can generate a variety of planning models to evaluate alternative water resources development schemes. However, the application of MODCOP to other models, which are substantially different from the one described in this report, probably will require extensive rewriting of the computer program.

This report describes the MODCOP program as applied to the Puerto Rico Water Resources Planning Model and its use with MPSX. The first part of the report briefly describes the structure of the planning model. The second part discusses the operation of MODCOP together with the preparation and formatting of the input data. Finally, use of the program in conjunction with MPSX is illustrated by an example.

Acknowledgments

The Puerto Rico Water Resources Planning Model is being developed as part of a cooperative program between the Commonwealth of Puerto Rico's Environmental Quality Board and the U.S. Geological Survey. The authors gratefully acknowledge the assistance of the Puerto Rico Environmental Quality Board, the Aqueduct and Sewer Authority, the Planning Board, the Department of Natural Resources, the Department of Public Works, the Puerto Rico Water Resources Authority, the Puerto Rico Industrial Development Co., and the Department of Agriculture in providing ready access to pertinent data, files, and reports.

PUERTO RICO WATER RESOURCES PLANNING MODEL

The Puerto Rico Water Resources Planning Model is a mixed-integer program which aids the planner in screening large numbers of water resources projects proposed for possible implementation. Given a set of future water demands, the mathematical program selects and schedules the construction of proposed projects so that the demands are met at minimum present cost. Similar planning models utilizing mixed integer programming are described by O'Neill (1972) and Facet and Marks (1972).

A schematic representation of one region in the planning model is shown in figure 1. In any given planning region, water demands may be met from a number of different sources. Raw water may be obtained from reservoirs, run-of-the-stream diversions, or it may be imported from some other planning region. Treated water may be obtained from ground-water fields (water is assumed to be chlorinated at the pumphouse), desalination plants, treated-water imports, or raw water may be processed at a water treatment plant. Thus the raw water demands may be met from either raw water or treated water supplies, while treated water demands may be only satisfied from treated water supplies. In addition to filling internal water demands, the region may also export raw or treated water to meet demands in other regions.

For each type of project, e.g., diversions, reservoirs, ground-water fields, desalination plants, water treatment

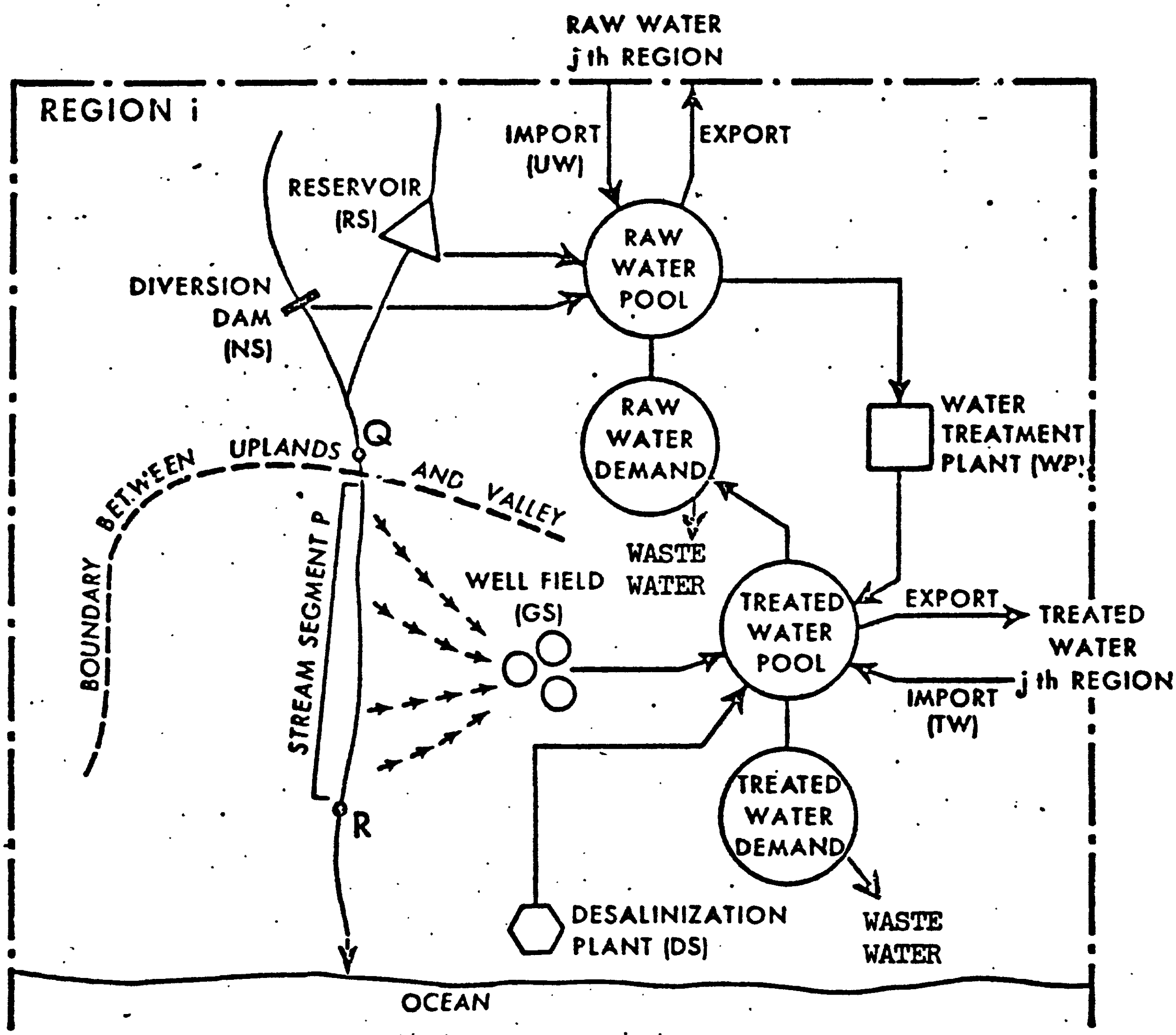

Figure 1. -- Schematic representation of the i-th region in the Puerto Rico Water-Resources Planning Model (MODCOP version 3).

plants, and raw or treated water import systems, the planner may wish to consider one or more different size projects located at different points within the region. For each proposed project the planner must estimate the project's yield or capacity, construction costs, operation-maintenance-replacement (OMR) costs per unit of water produced, transported, or processed, and the project's economic life.

For legal or environmental reasons the planner may wish to require that downstream flows equal or exceed a required flow value RFLOW. If ground-water development takes place in valley aquifers, ground-water surface-water interactions may cause water from the stream to recharge the ground-water supply. Eventually, the inflow to the valley from the uplands, QFLOW (fig. 1), may be reduced by drafts on diversions and reservoirs to the point where there is insufficient flow to <u>both</u> recharge the aquifer and meet downstream flow requirements. Therefore, the planning model has a constraint which represents the interactions between surface-water and ground-water development in the planning region and flow requirements at points specified by the planner.

In summary, the planning model consists of two or more planning regions interlinked by one or more water transfer projects (fig. 2). The model minimizes the present (or discounted) total cost of construction and operation of water resources projects in all regions over the planning horizon.

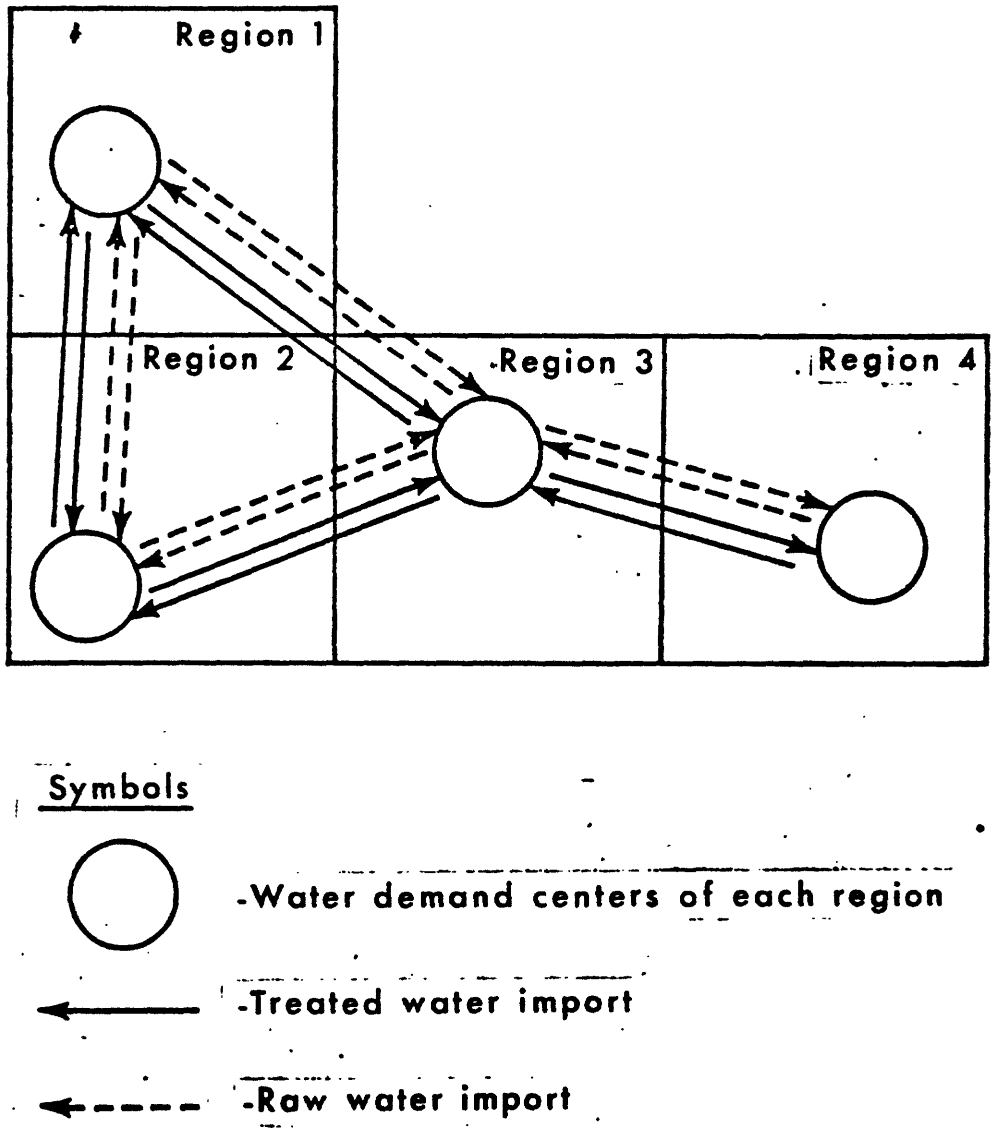

Figure 2. -- A schematic representation of a four-planning region model.

Mathematical Structure

A mixed-integer program determines a set of activity levels that optimizes an objective function subject to a set of constraints. Some of these activity levels are integer variables and others are continuous variables. The objective function of the Puerto Rico Water Resources Planning Model consists of minimizing the sum of the operating costs associated with producing, processing, and transporting a certain volume of water and the fixed construction costs associated with the individual projects (eq. 1). All costs are discounted to present value. The notation used in describing the objective function and the constraints is given in appendix A. The model's objective function is

$$\text{Minimize} \sum_{k=1}^{5} \sum_{n=1}^{N} \sum_{i=1}^{I} \sum_{l=1}^{L_{ik}} \left(C_{nil}^{(k)} Q_{nil}^{(k)} + FC_{nil}^{(k)} I_{nil}^{(k)} \right)$$

$$+ \sum_{k=6}^{7} \sum_{n=1}^{N} \sum_{i=1}^{I} \sum_{\substack{j=1 \\ i \neq j}}^{I} \sum_{l=1}^{L_{ik}} \left(C_{nijl}^{(k)} Q_{nijl}^{(k)} + FC_{nijl}^{(k)} I_{nijl}^{(k)} \right) \quad \text{(eq. 1)}$$

The first term of the objective function represents the operating costs and fixed costs of diversions, reservoirs, well-fields, desalinization plants, and water treatment plants. The second term represents the operating costs and fixed costs of raw and treated water imports.

The objective function is subject to the following constraints:

1. Project initiation constraint -- No water may be provided from project l of type k in planning region i until the project has been constructed. Furthermore, once constructed, the project cannot provide more water than its yield or capacity. For water production projects,

$$U_{il}^{(k)} \sum_{n=1}^{n'} I_{nil}^{(k)} \geq Q_{nil}^{(k)} \quad k = 1,\ldots,5;\ n' = 1,\ldots,N;\ i = 1,\ldots,I;\ l = 1,\ldots,L_{ik} \qquad \text{(eq.2a)}$$

and for water import projects,

$$U_{ijl}^{(k)} \sum_{n=1}^{n'} I_{nijl}^{(k)} \geq Q_{nijl}^{(k)} \quad k = 6,7;\ n' = 1,\ldots,N;\ i = 1,\ldots,I;\ j = 1,\ldots,I;\ i \neq j;\ l = 1,\ldots,L_{ik} \qquad \text{(eq. 2b)}$$

If project l of type k in planning region i already exists in the first planning period, then equation 2a or 2b can be replaced by a bound on the column variables which takes the following form:

$$0 \leq Q_{nil}^{(k)} \leq U_{il}^{(k)} \quad n = 1,\ldots,N \qquad \text{(eq. 3a)}$$

or

$$0 \leq Q_{nijl}^{(k)} \leq U_{ijl}^{(k)} \quad n = 1,\ldots,N \qquad \text{(eq. 3b)}$$

2. Project limitation constraint -- Project l of type k in planning region i may be constructed once and only once during the design horizon. For water production projects,

$$\sum_{n=1}^{N} I_{nil}^{(k)} \leq 1 \qquad k = 1,\ldots,5;\ i = 1,\ldots,I;$$
$$l = 1,\ldots,L_{ik} \qquad \text{(eq. 4a)}$$

and for water import projects,

$$\sum_{n=1}^{N} I_{nijl}^{(k)} \leq 1 \qquad k = 6,7;\ i = 1,\ldots,I;\ j = 1,\ldots,I;$$
$$i \neq j;\ l = 1,\ldots,L_{ik} \qquad \text{(eq. 4b)}$$

If project l of type k in planning region i already exists, this constraint is unnecessary.

3. Treated water demand constraint -- treated water production or processing (the output of well fields, desalinization plants, and water treatment plants) and treated water imports minus exports in planning region i and time period n must be equal to or greater than treated water demands of planning region i and time period n.

$$\sum_{l=1}^{L_{ik}} \left[\sum_{k=3}^{5} Q_{nil}^{(k)} + \sum_{\substack{j=1 \\ i\neq j}}^{I} \left(Q_{nijl}^{(7)} - Q_{njil}^{(7)}\right) \right] \geq DFW_{ni}$$

$$n = 1,\ldots,N;\ i = 1,\ldots,I \qquad \text{(eq. 5)}$$

4. Total water demand constraint -- Total water production (the output of diversions, reservoirs, ground water fields, and desalinization plants) plus the imports of raw and treated water minus exports in planning region i and time period n must be equal to or greater than the total water demand of planning region i in time period n.

$$\sum_{l=i}^{L_{ik}} \left[\sum_{k=1}^{4} Q_{nil}^{(k)} + \sum_{k=6}^{7} \sum_{\substack{j=1 \\ i \neq j}}^{I} \left(Q_{nijl}^{(k)} - Q^{(k)} \right) \right]$$

$$\geq DFW_{ni} + DIW_{ni} \qquad n = 1,\ldots,N; \; i = 1,\ldots,I$$

(eq. 6)

5. Flow requirement constraint -- The sum of the natural (unregulated) upland streamflows in planning region i in any time period n which discharge into stream segment p, minus withdrawals from the stream system by upland diversion, reservoir, and raw water export projects, and minus losses from the stream due to ground water recharge induced by aquifer pumping must be greater than or equal to the required flows downstream of the well fields.

$$\left(Q_{ip}^{*} - \sum_{k=1}^{2} \sum_{\hat{l}_{pk}} Q_{ni}^{(k)} \right) - \sum_{\hat{l}_{p3}} \sum_{t=1}^{n} f_{n-t+1,i,l} \, Q_{til}^{(3)} \geq R_{ip}$$

$$n = 1,\ldots,N; \; i = 1,\ldots,I; \; p = 1,\ldots,P_i \qquad \text{(eq. 7)}$$

The term in parentheses represents the streamflow available for recharging the aquifer in stream segment p. The vector $\hat{l}_{pk}$ is a list of project numbers (l) of type k which affect the flows in stream segment p. The vector $\hat{l}_{p3}$ denotes a list of ground water fields which interact with stream segment p. The final term of the constraint computes the losses from the stream in segment p during time period n induced by the present and past pumpage of well field l.

6. Bounds on integer variables -- All integer variables are bounded between zero and one

$$0 \leq I_{nil} \leq 1 \quad n = 1,\ldots,N;\ i = 1,\ldots,I;\ l = 1,\ldots,L_{ik} \qquad \text{(eq.8a)}$$

$$0 \leq I_{nijl} \leq 1 \quad n = 1,\ldots,N;\ i = 1,\ldots,I;\ j = 1,\ldots,I;$$

$$i \neq j;\ l = 1,\ldots,L_{ik} \qquad \text{(eq.8b)}$$

7. Non-negative constraint on continuous variables.

$$Q^{(k)}_{nil} \geq 0 \quad k = 1,\ldots,5;\ n = 1,\ldots,N;\ i = 1,\ldots,I;$$

$$l = 1,\ldots,L_{ik} \qquad \text{(eq. 9a)}$$

$$Q^{(k)}_{nijl} \geq 0 \quad k = 6,7;\ n = 1,\ldots,N;\ i = 1,\ldots,I;$$

$$j = 1,\ldots,I;\ i \neq j;\ l = 1,\ldots,L_{ik} \qquad \text{(eq. 9b)}$$

3. A planning region contains one or more complete river basins. Where possible the boundaries of a region should coincide with political boundaries in order to simplify data compilation for water demands.

4. Waste water return flows are not considered as a potential source of water through either direct reuse, downstream storage or diversion, or recharge of the ground water supply. In other words once water has been extracted from a given supply, it is assumed to be removed from the hydrologic system.

Additional assumptions are described in association with parameter definitions.

Model Assumptions and Definitions of Parameters

The Puerto Rico Water Resources Planning Model described by equations 1 through 9 may be used to represent a variety of water supply planning problems by changing the size of the planning regions, the length of a planning period, the number of planning periods in the planning horizon, and level of aggregation of water demands and water supply projects. Obviously, the choice of levels of aggregation and the operational definitions given to model parameters will affect the interpretation of the results of model optimization. The following assumptions and tentative definitions of parameters are given with a minimum amount of rationalization.

1. The minimization of water resource investments over the planning horizon and discounted to present value is a satisfactory criterion for evaluating alternative projects in a screening model.
2. Water resources projects proposed for development are associated with a specific site whereas water demands are assumed to be aggregated at a single point. It will often be convenient to assume that the raw and treated demand centers, raw and treated water pools, and water treatment plants are all located at the same point.

Cost Coefficients

The determination of fixed and operating costs of projects depends upon the way in which projects are defined. The current model makes a distinction between projects which transport water within a planning region and projects which transport water between planning regions. Thus, the costs of reservoir and diversion projects include the costs of transporting water to the nearest water treatment plant. Such transport costs might include a diversion dam downstream of the reservoir, if the stream channel is used to transport reservoir releases earmarked for water supply, pipelines, and pumping stations.

Construction costs of ground water fields and desalinization plants include the costs of transporting the water produced to the nearest connection within the existing water distribution system. Water treatment plant costs may or may not include transport costs depending on the location of the plant in relation to demand centers. The costs of expanding the existing water distribution system are not included in the model since such costs would be incurred regardless of the source of water.

Conceptually, water import project costs include the construction costs of pipelines and pumping stations needed to connect raw and treated water pools (fig. 1) in the exporting and importing regions. However, the actual costs of construction may include only a pipeline from a reservoir in one region to a raw water pool in another region, since the physical distance between project and raw water pool may be shorter than the distance between the regional raw water pools. In such a case care must be taken to assure that if the import project is built, the reservoir is also built.

Another problem involves the handling of nonlinearities in the cost functions. Both operating costs and fixed costs are generally nonlinear with respect to capacity. Since the planner has already fixed the size of the alternative projects that he wishes to screen with the model, fixed costs are determined before the model is run. The quantity of water produced, processed, or transported, however, is a decision variable. The model assumes that the operating cost function can be determined by a linear approximation of the function in the range of water quantities demanded from the project. If this assumption does not hold, then adjustments in the operating cost coefficients will have to be made and the model will have to be reoptimized.

Water quantities

The continuous variables, i.e., the Q-values in the model are decision variables which represent the quantity of water produced, processed, or transported during the planning period. While the total quantity of water may vary from planning period to planning period, the rate (expressed in millions of gallons per day) is assumed to be constant during any given planning period.

Project capacities and yields

The design capacities of pipelines, desalination plants, and water treatment plants are determined by using standard engineering techniques and assumptions about system reliability. The yields of reservoirs, diversions, and well fields, however, present problems of definition. The yield of a reservoir, for example, depends upon its capacity (usable storage), the pattern of inflows and drafts, its operating rules, and the way in which project "reliability" is defined. The planning model assumes that the planner conducts separate hydrologic studies of proposed reservoirs, diversions, and ground water fields to obtain initial estimates of project yield. These studies take into account seasonal (possibly monthly) variations in both inflow and draft rates as well as other storage requirements for such purposes as flood control and low flow augmentation in the case of reservoirs. These initial estimates are used to obtain draft rates on each project from the planning model. At this point additional hydrologic studies may be undertaken to refine the yield estimates.

Flow Requirement Constraint

The flow requirement constraint parameters (eq. 7) require some explanation. First, the model assumes that waste water discharges enter a stream below ground water recharge areas (see assumption no. 4 listed above). It also assumes that the planner may wish to impose a constraint that requires a minimum quantity of water (R_{ip}) to be available below stream reach p for diluting these waste water discharges in order to maintain water quality standards in the stream. The aggregate unregulated inflow from the uplands to stream reach p over the planning period will be Q^*_{ip}. With the development of upland reservoir and diversion sites some water will be removed from the system. Similarly, with the development of aquifers hydraulically connected to the stream along reach p, the stream will become a source of water with which to recharge the aquifer. Thus, the term

$$\sum_{t=1l}^{n} f_{n-t+1,i,l} \; Q_{til}^{(3)}$$

represents the aggregate amount of water removed from the stream during time period n due to pumping of the well field in time period n and all previous time periods.

The coefficient $f_{n-t+1,i,l}$ may be interpreted as the fraction of water pumped by field l in time period t that is removed from the stream in time period n.

The computation of the coefficient f is based on the use of a digital ground water model (Maddock, 1969). Given that the vertical flow in an aquifer is insignificant, it is possible to construct a function relating the pumping of a set of wells to the drawdown at those wells even if the aquifer has irregularly shaped boundaries and nonhomogenous flow parameters such as transmissivity and storage coefficients (Maddock, 1972). Assuming that the head boundary is constant along the surface water stream, Maddock (1973) derived an expression relating the amount of water withdrawn from ground water storage by a well to the storage coefficient of the aquifer, the drawdown at the well, and the surface area of the aquifer. The difference between the amount of water pumped and the amount removed from storage is the amount of water removed from the surface water stream.

Let

$$F(n) = \sum_{t=1}^{n} \sum_{j=1}^{M} \left[1 - \sum_{k=1}^{M} S(k)\ \Delta X^2\ \beta(k,j,n-t+1)\right] Q(j,t) \qquad \text{(eq. 10)}$$

where

$F(n)$ = cumulative quantity of water withdrawn from stream since pumping began.

$S(k)$ = storage coefficient of the k-th cell of the ground water model.

ΔX^2 = area of each cell in the ground water model.

$\beta(k,j,n-t+1)$ = the response matrix for time period t relating the drawdown of well k to unit pumping at well j; well k is located in the k-th well of the model.

$Q(j,t)$ = the quantity of water pumped at the j-th well in time period t.

M = number of wells in the ground water model

m = number of wells

n = number of time periods

The β coefficients are obtained by calibrating the ground water model with historical water level and pumping information.

By replacing the quantity in brackets by a coefficient, eq. 10 can be rewritten as

$$F(n) = \sum_{t=1}^{n} \sum_{j=1}^{m} \psi(j,n-t+1)\ Q(j,t) \qquad \text{(eq. 11)}$$

Computational experience with the model has shown that once a pumping pattern is established among the j wells of a well field, the pattern remains fairly constant from time period to time period. The individual well pumpages can then be replaced by $\alpha(j)Q(t)$ where $Q(t)$ is total water pumped during time period t and $\alpha(j)$ is the fraction of the total quantity of water pumped by well j. Thus, the ψ coefficient for the entire well field becomes

$$\psi_{(n-t+1)} = \sum_{j=1}^{m} \psi(j,n-t+1)\,\alpha(j) \qquad \text{(eq. 12)}$$

Thus, each well field l in each planning region i will have a coefficient $\psi_{n-t+1,i,}$ computed for it. The f coefficient in eq. 7 can now be written

$$f_{n-t+1,i,l} = \begin{cases} \psi_{1,i,l}, & n = 1 \\ \\ \psi_{n-t+1,i,l} - \psi_{n-t,i,l}, & n > 1 \end{cases} \qquad \text{(eq. 13)}$$

MODEL DEFINITION AND CONTROL PROGRAM (MODCOP)

The model definition and control program (MODCOP) was written to assist the planner prepare input data to MPSX and to optimize the model described in the preceding section of this report. It is assumed that the user is familiar with linear programming and the use of MPSX (IBM, 1971).

The problem matrix which describes the planning model to MPSX consists of five major sections (figure 3):

1. Objective function -- a single row vector of cost coefficients across the top of the matrix;
2. Bounds -- upper and/or lower bounds which constrain the values that the column variables may assume;
3. Right-hand side -- a column vector of values which represent the right-hand side (RHS) of the constraint equations;
4. Ranges -- a column vector of values which allow the RHS of the constraint equations to vary by fixed amounts;
5. The main body of the problem matrix is divided into as many submatrices as there are planning regions.

Each position in the problem matrix is labeled by a column name and a row name.

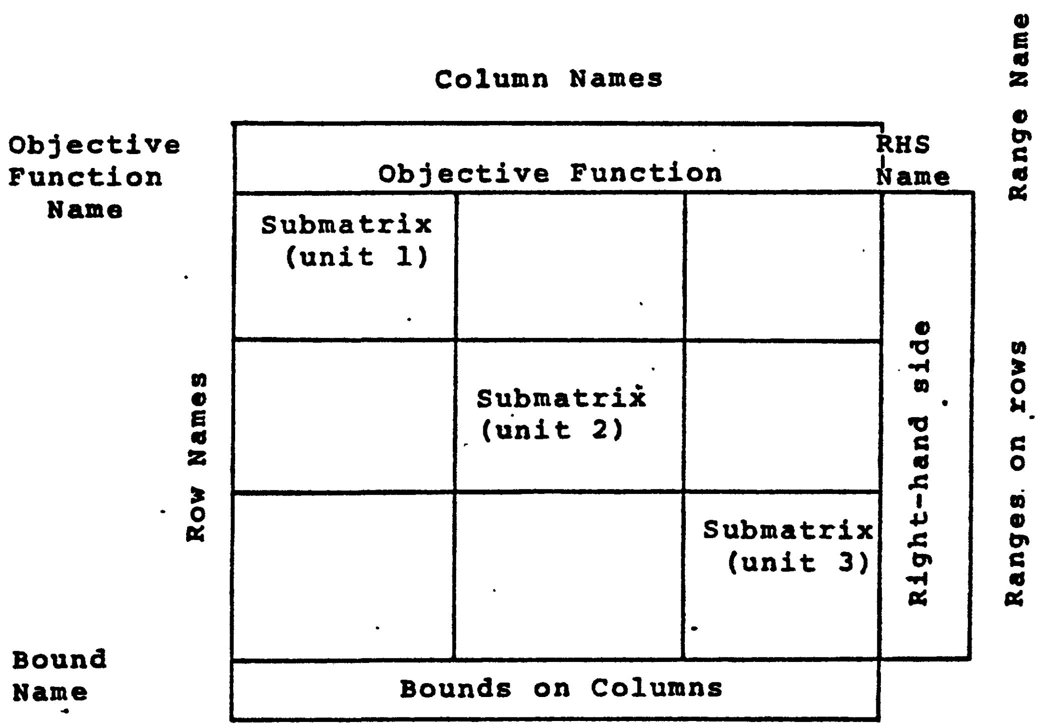

Figure 3. -- Problem matrix nomenclature. There are as many submatrices in the planning model as there are planning regions. The column variables of each submatrix consist of continuous variables and integer variables.

MODCOP is programmed to prepare control cards and data cards required by MPSX to solve the Water Resources Planning Model. The required cards and their format are described in the MPSX program description manual (IBM, 1971a). In general, once the appropriate equations of the mathematical program have been written (eqs. 1-9), a sample problem matrix should be filled in by hand with column names, row names, and the values of coefficients for each non-zero matrix element. Care should be taken to check and recheck the pattern of non-zero matrix elements to insure that they agree with the equations which describe the model. Later, this "picture" of the matrix can be compared with a picture produced on the computer's line printer by MPSX's PICTURE statement to verify the MPSX input data produced by MODCOP.

Program Organization and Operation

MODCOP calls on two main subroutines: DATA reads control cards and input data, and PR sets up the MPSX control data and input data and transfers the card images to disk storage.

Subroutine DATA

Subroutine DATA reads MODCOP control cards and input data, prints tables of input parameters for verification by the user, and computes interest rates, annual fixed costs, ground-water coefficients, and various other model parameters. Table 1 summarizes the cards read by this subroutine. Their formats are given in appendix B.

Each of the 12 types of data cards is preceded by a header card which is used by the subroutine to verify that the proper cards are being read. If the proper header card is not read, the program prints out an error message, although it does not terminate operation.

Model initialization parameter control cards. -- The first of these two control cards contains four names which are used to identify the MPSX data deck, the objective function row, the right-hand side column, and bounds rows. Each name may be up to eight characters long. The first character of each name must be a letter and the name must not contain embedded blanks. The last parameter of the first card XWRITE

Table 1. -- Summary of MODCOP input data cards

1. Model initialization parameter control cards.
2. Row and Column name symbol cards.
3. Number of water production (or processing) project cards.
4. Number of raw water import project cards.
5. Number of treated water import project cards.
6. Water production project parameter cards.
7. Raw water import project parameter cards.
8. Treated water import project parameter cards.
9. Water demand cards.
10. Surface water - ground water interaction parameter cards.
11. Surface water flow requirements cards.
12. Planning unit and project index cards.

may be set to 'YESb̸', where b̸ represents a blank character, if the card images produced by the PR subroutine are to be displayed on the line printer.

The second card specifies the number of planning regions NPLAN, the number of time periods NTIME, the length of a time period in years TIME, the annual present value interest rate RPV and the annual amortization interest rate RAM. The subroutine converts the annual present value interest rate to the effective interest rate for a planning period using the following equation:

$$R = (1. + RPV)^{TIME} - 1. \qquad \text{(eq. 14)}$$

All parameters are displayed in a table.

Row and column name symbol cards. -- The first card in this section gives the number of row symbols (NRSYMB) and the number of column symbols (NCSYMB) to be read from the cards to follow. A third parameter NP gives the number of types of water production (or water processing) projects as distinct from water import projects. The planning model described in this report has seven types of water resources projects, five of which are water production projects, e.g., diversions, reservoirs, ground water fields, desalinization plants, and water treatment plants. Thus, NP should be set to 5.

Each three-character symbol is displayed on a separate card with row symbols preceding the column symbols. In the planning model different symbols are used in place of the project type or k index. Each group of row constraints should be clearly identified by different row symbols and continuous column variable symbols should be distinguishable from integer column variables. All symbols are displayed in a table. If the cards are out of order, e.g., row symbol 10 is read when the program expected row symbol 9, an error message is printed but processing continues.

<u>Number of water production (or water processing cards)</u>. -- These cards provide the number of <u>existing</u> and <u>proposed</u> projects in each planning region by type, e.g., diversions, reservoirs, etc. There must be <u>one</u> card for each planning region. If there are no projects of a particular type of planning unit, a zero is entered in the appropriate column position. A maximum of 10 projects of each type is currently allowed in the program. The number of projects in each planning region are displayed in a table. If a card for a planning region is missing or the cards are out of planning region order, an error message will be printed.

<u>Number of raw water import project cards</u>. -- These cards give the number of raw water <u>import</u> projects in each planning region. Each card has three variables: I, the planning region <u>importing</u> water; J, the planning region <u>exporting</u> water; and NPIMP(I,J), the number of transport projects (maximum of 10 projects). There must be at <u>least</u> one card

for each planning region. If planning region I does not import water, J and NPIMP(I,J) should be set equal to zero. In any case, the last card of a group of one or more cards for each planning region must have J = 0 and NPIMP(I,J) = 0 in order to terminate the read cycle for each planning region. After reading the cards, the program displays the number of projects in a table. If the cards are not in planning-region order, an error message will be printed.

Number of located water import project cards. -- These cards give the number of treated water import projects in each planning region. The description of the "Number of raw water import project cards" is applicable to these cards except that the number of projects is given by the variable NPIMQ(I,J).

Water production project parameter cards. -- These parameter cards describe the economic life NL, the yield (or capacity) YLD, the fixed costs CF, and the operating costs per million gallons CO for each water production project in each planning region. The total number of cards must be equal to the total number of production projects. In addition to the information above, existing projects must be identified by setting FIX = 1.

After reading the project parameters, the DATA subroutine calls another subroutine, ACOST, to compute the discounted fixed costs of each project for each planning period during which it might be constructed. The capital recovery factor CFR is calculated as follows:

$$CFR = \frac{RAM(1. + RAM)^{NL}}{(1. + RAM)^{NL} - 1.} \qquad \text{(eq. 15)}$$

where RAM is the interest rate to be used in amortizing the capital costs of the project over its economic life NL expressed in years. The annual fixed costs AFC are then obtained by multiplying the fixed costs CF by the capital recovery factor.

$$AFC_{il}^{(k)} = CFR \quad (CF_{il}^{(k)}) \qquad \text{(eq. 16)}$$

The data subroutine also converts project yields and capacities from millions of gallons per day (MGD) to millions of gallons per planning period. Finally, all data and the results of the computations are displayed in a table.

Raw water and treated water import project parameter cards. --These two types of cards contain the same kinds of information as is on the water production project parameter cards. One card must be prepared for each project.

Water demand cards. -- This set of cards gives the future demands for fresh (treated water) DFW and for raw water DIW by land unit. Water loss factors are also given for each type of demand and indicate the fraction of the water supplied that is lost in transmission and treatment. The program then adjusts the given water demands upwards to compensate for these expected losses. For example,

$$DFW \text{ (adjusted)} = DFW / (1. - PLFW) \qquad \text{(eq. 17)}$$

The total water demand for a given planning period in a given planning region is the sum of the adjusted raw and treated water demands. The program displays both the unadjusted water demands in MGD, and then the adjusted demands in MG per planning period. There must be NPLAN* NTIME water demand cards in the data deck.

<u>Surface water - ground water interaction parameter cards</u>. -- If a well field is developed in an aquifer which is hydraulically connected to a river whose flow is also developed as a water supply, then the interaction between the two sources of supply must be taken into account in evaluating the quantity of water that may be pumped. In general, if ground water is developed first, then as demands increase beyond the capacity of the well fields, upland surface water sources are developed. Withdrawals from these sources reduce the amount of water available for recharging the aquifer which in turn reduce the water available from the ground water system.

If the planner believes that these interactions are important, then he must supply for each well field a set of coefficients PHI which reflect the amount of water lost from a stream in this and future planning periods due to unit pumping of the well field in the current time period. If there is no interaction, then the PHI values are set to zero.

Each surface water - ground water interaction card contains the PHI values for NTIME time periods for ground water field l in planning region i. After reading the PHI values, equation 13 is used by subroutine GWCØMP to compute coefficients for for the ground water decision variables $Q^{(3)}$. All values are printed in tables. If no ground water projects are in the model, this section of data input must be skipped.

Surface water flow requirements cards. -- For one or more stream segments in a region, the planner may wish to set up flow requirements. This flow requirement states that the natural runoff of the region must exceed the ground water and surface water withdrawals by a certain amount.

The first card in this section lists the number of points at which flow requirements are necessary. One card must be provided for each planning region. The next two cards are read by the program in pairs: the first card gives the natural upland flow QFLOW, the flow requirement RFLOW, and the index number of the stream segments of interest. The second card identifies those reservoir and diversion projects whose withdrawals must be subtracted from QFLOW in addition to those ground water pumpages which induce recharge from the stream and therefore decrease the flow of the stream. In this way several flow requirements on a single stream or on several different streams within a single planning region can be accommodated. There must be one pair of cards for each flow requirement point in the model.

Planning unit and project index cards. -- The final set of cards in the input data to MODCOP is optional. They are for the convenience of the user and allow him to label any or all of the various planning regions and projects. Whenever an end-of-file card is encountered, subroutine DATA is terminated.

Subroutine PR

Subroutine PR in MODCOP transcribes the data read by subroutine DATA into the format required by MPSX.

The MPSX input data may be divided into seven sections:

1. NAME of data deck.

2. ROWS section specifies the row names of the problem matrix and the type of each row constraint.

3. COLUMNS section specifies the column variable names of the problem matrix and the value of each nonzero matrix element. The position of the element is given by a column name and a row name. Marker cards are inserted in this section to identify where integer column variables begin and end.

4. RHS section specifies the name of the right-hand side column vector and the nonzero values of the row constraints. The matrix elements are identified by the RHS name and row name.

5. RANGES section used when a row is to represent both a $\geq$ and $\leq$ inequality constraint. The section is optional and is not used in the current version of the Puerto Rico Planning Model.

6. BOUNDS section specifies the limits to be imposed on the values of the column variables and the type of bounds. Normally, the MPSX automatically assigns a lower bound of zero and an upper bound of $+\infty$ to all column variables. Each nonzero bound value is identified by the Bound name and a column name. Note that all integer variables in the planning model must have an upper bound of one.

7. ENDATA card signifies the end of the data deck.

With the exception of the RANGES section, which is not used in the planning model, subroutine PR is programmed to write card images on disk for each of the sections listed above. If XWRITE = 'YESb' on the first model parameter card read by subroutine DATA, the card images will also be printed.

NAME section. -- Writes the NAME card and assigns PNAME to the data deck name.

ROWS section. -- The program writes the name of the objective function OBNAME, as the first row name and identifies it as an unconstrained row (type N). The program then loops through each planning unit writing the row names of constraints in the order that they are given in equations 2 through 10. The row (and column) names are created as follows: The number of the planning region (I or J index) is converted to a letter, e.g., A = 1, B = 2, etc. Then the appropriate three-character row symbol (RSYMB(K)) is concatenated with the planning region letter, the planning period number (N), and the project number (M). In the case of import projects a second letter (J index) is inserted after the first letter to indicate the source of the imported water.

The cost coefficients of the integer column variables are calculated from the projects annual fixed costs (eq. 16). Each annual fixed cost payment made during the economic life of the project or during the number of years remaining in the planning horizon, whichever is smaller, is discounted to present value and summed as shown in eq. 18.

$$FC_{ni\ell}^{(k)} = \sum_{t=t_1}^{t_2} \frac{1}{(1.+RPV)^t} AFC_{i\ell}^{(k)} \quad \text{(eq.18)}$$

where $FC_{ni\ell}^{(k)}$ - present value of equivalent fixed cost payment assumed to be made during the first year of time period n.

t_i - year in which payment is made; t_1 = N · TIME - TIME + 1 where TIME is the number of years in a planning period and N is the number of the planning period.

t_2 - year in which payments end; t_2 = N · TIME + NL or t_2 = NTIME · TIME, whichever is smaller, where NL is the economic life of the project in years and NTIME is the number of planning periods in the planning horizon.

RPV - annual discount rate

$AFC_{i\ell}^{(k)}$ - annual fixed cost payment for project ℓ of type k in planning region i.

The only zero coefficients in the objective function row will be the fixed costs of existing projects.

The row constraints are written in the following order:

1. Project initiation constraints for water production and water import projects (eq. 2a and 2b).
2. Project limitation constraints for water production and water import projects (eq. 4a and 4b).
3. Treated water demand constraints (eq. 5).
4. Total water demand constraints (eq. 6).
5. Flow requirements constraints (eq. 7).

COLUMNS section. -- The columns section is written in two parts: the continuous variable section and the integer variable section. Marker cards are inserted before and after the integer variable section. The column names are created as described for the ROWS section. To determine which matrix elements are nonzero for any given column variable, the user should rewrite the constraints in such a way that the column variables appear in the constraint in the same order that they are to be written by subroutine PR. The order is determined by the column symbol list CSYMB(K) and the DO-loops indexed on planning unit I (and J for import projects), the planning period N, and the project number M, if appropriate to the constraint.

The first row of each column vector will always contain a cost coefficient. For the continuous variables column, the cost coefficients in the objective function are the present values of operating costs per unit of water produced or transported, COP. COP is calculated from the operating costs CO, COIMP, and COIMQ read by subroutine DATA. For example,

$$COP = \frac{CO}{(1. + R)^{N}} \qquad \text{(eq.19)}$$

where R is the effective interest rate for a planning period (eq. 14) and N is the number of the planning period.

The program then writes any nonzero values in the column vector together with the row name. Coefficients with values of 1 or -1 are usually written as part of a format statement in the computer program. Other values, such as project capacity must be read by subroutine data. If new constraints are added to the model, the user must determine which rows have nonzero coefficients and develop the logic of whether or not to write a coefficient in a particular column. The logic and appropriate write statements and formats must be added to this section of the PR subroutine.

RHS section. -- The nonzero right-hand-side values of each row constraint are next written in the same order as the row names were defined. The RHS column is given the name assigned to RHNAME on the first model parameter card read by subroutine DATA. The program also creates four additional columns as part of the RHS section. The first column vector, XCHCOLR1, duplicates the treated water and total water demands in the RHS column. The second, XCHCOLR2 duplicates the RHS of the required flows constraint bearing in mind that this value is the difference between the natural inflows and the required flows (QFLOW-RFLOW). Column XCHCOLR3 and 4 contain negative values of columns XCHOLR1 and 2 respectively. These four "change" columns and the RHS are used for parametric program using the MPSX procedure PARARHS.

BOUNDS section. -- The program next writes out the bound row vector, which is given the name assigned to BNAME on the first model parameter and read by subroutine DATA. All withdrawals from water producing or transporting projects are bounded by their yields and capacities. All integer variables are given upper bounds of one.

ENDATA section. -- The last step in subroutine PR is to write an 'ENDATA' card to complete the MPSX data deck.

Subroutine BLOCK DATA

The final subroutine in MODCOP that should be mentioned is BLOCK DATA. This subroutine initializes the values of data arrays that are shared in common with the DATA and PR subroutines. The current dimensions of data arrays in MODCOP version 3 are listed in table 2. If the user wishes to enlarge or reduce the dimensions of the current model for some reason, the dimension and initialization statements in BLOCK DATA will have to be changed as well as the appropriate COMMON statements in the DATA, PR, ACOST, and GWCOMP subroutines.

Table 2. -- List of variables dimensioned in subroutine BLOCK DATA

Variable Name	Description
RSYMB(25)	Row symbol list
CSYMB(25)	Column symbol list
NPROJ(K,I)	Number of water producing (or processing projects)
NPIMP(I,J)	Number of raw water import projects
NPIMQ(I,J)	Number of treated water import projects
NL(K,I,P)	Economic life of water producing projects
NLIMP(I,J,P)	Economic life of raw water import projects
NLIMQ(I,J,P)	Economic life of treated water import projects)
YLD(K,I,P)	Yield/capacity of water producing projects (MGD)
YLDIMP(I,J,P)	Capacity of raw water import projects (MGD)
YLDIMQ(I,J,P)	Capacity of treated water import projects (MGD)
CAP(K,I,P)	Yield/capacity of water producing projects (MG per planning period)
CAPIMP(I,J,P)	Capacity of raw water import projects (MG per planning period)
CAPIMQ(I,J,P)	Capacity of treated water import projects (MG per planning period)
CF(K,I,P)	Fixed costs of water producing projects
CFIMP(I,J,P)	Fixed costs of raw water import projects
CFIMQ(I,J,P)	Fixed costs of treated water import projects

Table 2. -- (continued)

Variable Name	Description
CO(K,I,P)	Operating costs for water production projects ($/MG)
COIMP(I,J,P)	Operating costs for raw water import projects ($/MG)
COIMQ(I,J,P)	Operating costs for treated water import projects ($/MG)
AFC(K,I,P)	Annual fixed costs for water production projects
AFCIMP(I,J,P)	Annual fixed costs for raw water import projects
AFCIMQ(I,J,P)	Annual fixed costs for treated water import projects
FXFLAG(K,I,P)	Logical flags for existing water production projects
IMPFIX(I,J,P)	Logical flags for existing raw water import projects
IMQFIX(I,J,P)	Logical flags for existing treated water import projects
DFW(I,N)	Demand for treated water (MG per planning period)
DIW(I,N)	Demand for raw water (MG per planning period)
TAD(I,N)	Total water demand (MG per planning period)
PLFW(I,N)	Treated water losses (percent/100)
PLIW(I,N)	Raw water losses (percent/100)
PHI(N,I,P)	Ground water - surface water interaction coefficient
F(N,I,P)	Ground water - surface water interaction coefficient
NPX(I)	Number of stream segments

Table 2. -- (continued

Variable Name	Description
QFLOW(I,KP)	Upland runoff above stream segments (MG per planning period)
RFLOW(I,KP)	Required flow below stream segments (MG per planning period)
KPDFL(I,KP,6)	Project linkage array
Index	
I,J	Index to planning regions: I = 8, J = 8.
K	Index to project type (water production or water processing projects only); K = 5.
KP	Index to stream segments; KP = 5.
P	Index to project number; P = 10.

Operating Requirements

The current version of MODCOP (version 3) is written for the IBM 360/65 computer in the FORTRAN IV programming language. The program requires 154 K bytes of storage to compile and approximately 250 K to execute. If the data arrays are increased, additional core may have to be allocated to the program for execution of the load module.

An error-free compilation of the source program takes about one minute. Execution time will depend upon the number of planning regions, planning periods, and projects in the model, but few models will require more than one minute.

MODCOP will usually be set up to write the MPSX data deck as card images on disk. To determine the disk space requirements of the MPSX data deck the user should first estimate the number of card images produced by MODCOP using the equations in table 3. If 90 card images are written in 7200-byte blocks per track, then the user should allocate [total number of cards / 90] + 1 tracks to MODCOP's output data set.

A complete listing of the source program is shown in appendix E.

Table 3.-- Equations for estimating the number of card images in a MPSX data deck produced by MODCOP (version 3). Note that these equations only apply to the Puerto Rico Water Resources Development Planning Model defined by equations 1 to 10.

Let n = total number of projects in all planning regions.

n_e = total number of existing projects in all planning regions.

n_k = total number of projects of type k in all planning regions.

t = number of planning periods.

q = total number of flow requirement points in all planning regions.

p = number of planning regions.

where

k =	Type of project
1	Diversion dams
2	Reservoirs
3	Ground water fields
4	Desalinization plants
5	Water treatment plants
6	Raw water import projects
7	Treated water import projects

Section of MPSX Data Deck		Number of Cards
NAME		1
ROWS		
1. Objective function		1
2. Initiation constraints (eq. 2)	$= (n-n_e)t$	
3. Limitation constraints (eq. 4)	$= n-n_e$	

Table 3. -- (continued)

4. Treated water demand constraints (eq. 5) = pt

5. Total water demands constraints (eq. 6) = pt

6. Flow requirement constraints (eq. 7) = qt

COLUMNS

1. Continuous variable section
   $= [4n_1+4n_2+4(n_3+t)+4n_4+3n_5+4n_6+6n_7]t$

2. MARKER cards for integer variables = 2

3. Integer variable section = $2(n-n_e)t$

RHS

1. Limitation constraints = $n-n_e$

2. Treated water demands constraints = pt

3. Total water demands constraints = pt

4. Flow requirement constraints = qt

BOUNDS

1. Continuous variables = nt

2. Integer variables = $(n-n_e)t$

ENDATA 1

MPSX USAGE

Before using MPSX the user should be familiar with the concepts of linear and integer programming. Wagner (1969), for example, provides a good introduction to these subjects. Geoffrion and Marsten (1972) review the state-of-the art of integer programming algorithms and include a discussion of MPSX. Finally, the user should carefully read the MPSX program description (IBM, 1971a and 1971b) for detailed instructions in the use of MPSX.

As an example of the use of MODCOP and MPSX, a two-region planning model was developed for the Yabucoa Municipio, Puerto Rico. The urban area of Yabucoa was treated as a single demand center with a second planning region representing the rest of the world. Demands in the rest of the world were assumed to be zero and an ample supply of raw and treated water was assumed to be available for importing to Yabucoa.

The first part of appendix D lists the input data to MODCOP. This listing is followed by the tables produced by MODCOP and a sample of the MPSX data deck created by MODCOP. Note that listing of MPSX data was obtained by setting XWRITE = 'YESb' on the first model initialization parameter control card (p. 24). The second part of appendix D illustrates the MPSX control program used to obtain an optimal integer solution to the problem and part of the MPSX program output. The problem consisted of 165 continuous column variables, 140 integer column variables, and 199 rows. The matrix density was 1.62. MPSX was able to prove optimality for this problem in 10 minutes on the IBM 360/65 and 3.8 minutes on the IBM 360/91 computer using the MPSX default search strategy.

SUMMARY

Within the limitations of the least-cost model described by equations 1 through 9, MODCOP offers the user considerable latitude in combining different types of water resources projects to approximate existing and proposed regional water resources development schemes. The use of the surface water-ground water interaction parameters introduces the impact of ground water pumping on surface water flows in areas where upland surface water development is likely to limit surface water available for ground water recharge. The mixed integer model described in this report does not provide optimal schemes of water resources development. All of the model's parameters, the cost coefficients, project capacities, future water demands, etc., are subject to uncertainty while the model provides a deterministic least cost solution to just one set of parameter estimates. On the other hand, given the assumptions upon which the model is based, the planner can explore a variety of water resources development proposals and eliminate or screen out those which are clearly more costly than others, and therefore probably less desirable. The successful application of this model will depend in large part on the planner's ability to identify potential development schemes, choose appropriate scales of parameter aggregation, and interpret the results of model optimization.

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Appendix A. -- Puerto Rico Water Resources Development Planning Model notation

Appendix A. -- Puerto Rico Water Resources Development Planning Model notation

Indexes	Description
k	Index to type of water resources project; $k = 1,\ldots,7$.
n	Index to time within a planning horizon of N periods; $n = 1,\ldots,N$.
i,j	Planning region or land unit index; $i = 1,\ldots,I$; $j = 1,\ldots,I$.
l	Project number index which specifically designates the location and size of a water resources project. The number of projects of type k will vary from region to region; $= 1,\ldots, L_{ik}$.
$\hat{l}_{p,k}$	List of project numbers of type k which affect the flow requirements downstream of stream segment p.
p	Number of stream segments for which there is a downstream flow requirement. The number of segments will vary from region to region; $p = 1,\ldots,P_i$.

k	Project
1	Diversion dam
2	Reservoir
3	Ground-water well field
4	Desalinization plant
5	Water treatment plant
6	Raw water import project
7	Treated water import project

Continuous Variables

$Q^{(k)}_{nil}$ Amount of water produced or processed by project l of type k in planning region i during time period n; $k = 1,\ldots,5$.

$Q^{(k)}_{nijl}$ Amount of water (raw or treated) imported by project l of type k in time period n from land unit j to land unit i. Exports from

Ground Water Coefficients	Description
f_{n-t} to $1,i,l$	Response of surface water recharge to unit pumping of well field l in planning region i during planning period n. The coefficient f may be interpreted as follows: if f = 0, then pumping of the ground water field has no impact on the stream; if f = 1, then all of the water pumped from project l in time period n is derived from the stream during the same time period; $0 \leq f \leq 1$.
$\psi_{n-t+1,i,l}$	The response function representing the interaction of unit pumping in well field l in planning region i with ground water recharge from surface water channel during pumping period t where n is the current planning period.

Water Demands

DFW_{ni}	Amount of treated water in million of gallons demanded by planning region i during time period n. (Demands are adjusted upwards to compensate for estimated processing and transmission losses).
DIW_{ni}	The amount of raw water in millions of gallons demanded by planning region i during time period n. (Demands are adjusted upwards to compensate for estimated transmission losses).
R_{ip}	The required flow in millions of gallons downstream of stream segment p in planning region i during any time period n.

Other Exogenous Variables

Q^*_{ip}	The sum of the natural upland discharges in millions of gallons to stream segment p in planning region i during any time period n.

Continuous variables (cont'd)	Description
	land unit i to land unit j are represented by switching the i and j indexes. Thus, an export from land unit i appears in the model as an import to land unit j; k = 6,7.

Integer Variables

$I^{(k)}_{ni\ell}$	Integer variables indicate when specific projects are to be constructed in each planning region. If I equals one, then project ℓ of type k will be constructed in planning region i during time period n. Otherwise, I equals zero; k = 1,...,5.
$I^{(k)}_{nij\ell}$	Integer variables indicating the construction of water import project ℓ of type k in time period n which transfers water from planning region j to planning region i; k = 6,7.

Cost Coefficients

$FC^{(k)}_{ni\ell}$ and $FC^{(k)}_{nij\ell}$	Discounted annual fixed costs associated with project ℓ of type k in region i and constructed in time n; k = 1,...,5 and k = 6,7.
$C^{(k)}_{ni\ell}$ and $C^{(k)}_{nij}$	Discounted operation, maintenance, and replacement costs per million gallons associated with project ℓ of type k in planning region i; k = 1, ...,5 and k = 6,7.

Capacity Coefficients

$U^{(k)}_{i\ell}$ and $U^{(k)}_{ij\ell}$	Design capacity or yield in millions of gallons of water resources project ℓ of type k in any time period n; k = 1,...,5 and k = 6,7.

Appendix A (continued)

Other Exogenous Variables (cont'd)	Description
N	Number of time periods of t years in the design horizon of the planner. If the design horizon is for T years, $N = T/t$.
I	Number of planning regions or land units to be studied.
L_{ik}	Number of projects of type k in each land unit.
P_i	Number of stream segments which have flow requirements in land unit i.
r	Effective interest rate for a single time period (t years) used to reduce monies to present values.

Appendix B. -- Format of MODCOP input data cards

Appendix B-1.-- Model initialization parameter control cards (REQUIRED)

Column	Variable Name	Description
Header Card		
1-4	INIT	'INIT' -- The remainder of the card may be used to describe the cards to follow.
Card 1		
1-8	PNAME	Problem name assigned to NAME card of MPSX data deck. The first character of all names must be alpha. The field is left justified as are all the names on card 1.
9-16	OBNAME	Objective function name assigned to the first row of the MPSX problem matrix.
17-24	RHNAME	Right-hand-side name assigned to the RHS column vector in the MPSX problem matrix.
25-32	BNAME	Bounds name assigned to the BØUNDS row vector in the MPSX problem matrix.
33-37	XWRITE	Parameter for controlling printout of the matrix created by MØDCØP. If 'YESb' is punched, the MPSX data card images will be printed 1/.
Card 2		
1-4	NPLAN	Total number of planning regions (maximum of 8).
5-8	NTIME	Total number of time periods in planning horizon (maximum of 10).

1/ The character b represents a blank.

2/ All numbers in this and following sections are right justified in their field positions.

Appendix B-1(continued)

Column	Variable Name	Description
Card 2 (cont'd)		
9-16	TIME	Length of time period in years (punch decimal point).
17-24	RPV	Present value interest rate (punch decimal point).
25-32	RAM	Amortization interest rate (punch decimal point).

Appendix B-2.-- Symbol control cards for row and column names (REQUIRED)

Column	Variable Name	Description
Header Card		
1-4	SYMB	'SYMB' -- The remainder of the card may be used to describe the cards to follow.
Card 1		
1-4	NRSYMB	Number of row symbols (maximum of 25).
5-8	NCSYMB	Number of column symbols (maximum of 25).
9-12	NP	Number of water producing or water processing _types_ of projects including water treatment plants but _not_ including water transport projects. Set NP to 5 for this version of the planning model.
Row or Column Symbol Cards		
1	--	"R" or "C" -- Identification of card type: row or column.
2-3	KK	Number of Kth symbol.
5-7	RSYMB(K) or CSYMB(K)	Three-character prefix of Kth row or column symbol. First character must be alpha.
8-80	RDESC(K,J) or CDESC(k,J)	Up to 72 characters of text describing the Kth row or column symbol.

Note: The row cards must precede the column cards in the data deck, and the cards must be in ascending order of the KK value. There will be a total of NRSYMB+NCSYMB symbol cards.

Appendix B-3.-- Number of water production (or water processing) projects cards (REQUIRED)

Column	Variable Name	Description
Header card		
1-4	NWPP	'NWPP'--the remainder of the card may be used to describe the cards to follow.
Planning Unit cards		
1-4	KK	Number of I-th planning region.
5-8	NPRØJ(1,I)	Number of diversion projects (include both existing and proposed projects here and in the following project types. Maximum of 10 projects).
9-12	NPRØJ(2,I)	Number of reservoir projects.
13-16	NPRØJ(3,I)	Number of well fields.
17-20	NPRØJ(4,I)	Number of desalinization plants.
21-24	NPRØJ(5,I)	Number of water treatment plants.
	.	
	.	
	.	

Note: The number of project types listed on this card depends upon the structure of the model and must agree with the value given NP on the symbol control cards, e.g., in this case, NP=5. If NP>5, additional fields must be supplied as indicated by the field continuation dots above. Also, the dimensions of the program will have to be changed (see table 2 for a list of the variables whose dimensions will have to be changed). The user must supply one card for each planning region in the model even if there are no water production projects in the planning region. Thus, there will be NPLAN planning region cards in the data deck.

Appendix B-4 -- Number of raw water import projects cards (REQUIRED)

Column	Variable Name	Description
Header Card		
1-4	NRWT	'NRWT' -- The remainder of the card may be used to describe the cards to follow.
Planning Unit Cards		
1-4	I	Number of the planning unit that imports water.
5-8	J	Number of the planning unit that exports water.
9-12	NPIMP(I,J)	Number of import projects (maximum of 10 projects).

Note: The following rules apply to the preparation raw water and treated water transport project cards (see appendix B-5):

1. There must be at least one card for each planning region in the model even if the planning region does not import water. In this case, J = 0 and NPIMP(I,J) = 0. This card will terminate the read cycle for the planning region.

2. The last card in a group of one or more cards for a planning region which does import water must have J = 0 and NPIMP(I,J) = 0 to terminate the read cycle for that planning region.

Appendix B-5. -- Number of treated water import project cards (REQUIRED)

Column	Variable Name	Description
Header Card		
1-4	NTWT	'NTWT' -- The remainder of the card may be used to describe the cards to follow.
Planning Unit Cards		
1-4	I	Number of the planning unit that imports water.
5-8	J	Number of the planning unit that exports water.
9-12	NPIMQ(I,J)	Number of import projects (maximum of 10 projects).

Note: See note for appendix B-4.

Appendix B-6. -- Water production project parameter cards (OPTIONAL)

Column	Variable Name	Description
Header Card		
1-4	FCWP	'FCWP' -- The remainder of the card may be used to describe the cards to follow.
Project Parameter Cards		
1-4	I	Number of planning region.
5-8	K	Project type code (appendix A).
9-12	L	Number of project. Project numbers must be assigned sequentially and grouped so that those which affect a given stream segment fall within the inclusive range of two project numbers (see appendix B-11).
10-16	NL(K,I,L)	Economic life of project in years.
17-26	YLD(K,I,L)	Yield or capacity of project in MGD (punch decimal point).
27-36	CF(K,I,L)	Fixed costs of project construction in dollars (punch decimal point). If project already exists, set value to zero.
37-46	CØ(K,I,L)	Operating costs per MG of water produced or processed in dollars (punch decimal point).
49	FIX	If the project currently exists, set FIX=1; otherwise, leave field blank.

NOTE: The "FCWP' header card is not required if there are no water production projects to be described. Normally, however, it will be present followed by one card for <u>each</u> existing or proposed water production card counted in the numbers reported on the Number of Water Production Projects cards (appendix B-3).

Appendix B-7. -- Raw water import project parameter cards (OPTIONAL)

Column	Variable Name	Description
Header Card		
1-4	FCRW	'FCRW' -- The remainder of the card may be used to describe the cards to follow.
Project Parameter Cards		
1-4	I	Number of the planning region that imports water.
5-8	J	Number of the planning region that exports water.
9-12	L	Number of project.
13-16	NLIMP(I,J,L)	Economic life of project in years.
17-26	CAPIMP(I,J,L)	Capacity of project in MGD (punch decimal point).
27-36	CFIMP(I,J,L)	Fixed costs of project construction in dollars (punch decimal point).
37-46	CØIMP(I,J,L)	Operating costs per MG of water imported in dollars (punch decimal point).
49	FIX	If project currently exists, set FIX=1; otherwise, leave field blank.

Note: The 'FCRW' header card is not required if there are no raw water import projects to be described. If there are raw water import projects, there must be one card for each existing or proposed project. The number of cards will be equal to the total number of projects reported on the Number of Raw Water Import Project cards (appendix B-4).

Appendix B-8. -- Treated water import project parameter cards (OPTIONAL)

Column	Variable Name	Description
Header Card		
1-4	FCTW	'FCTW' -- The Remainder of the card may be used to describe the cards to follow.
Project Parameter Cards		
1-4	I	Number of the planning region that imports water.
5-8	J	Number of the planning region that exports water.
9-12	L	Number of project.
13-16	NLIMQ(I,J,L)	Economic life of project in years.
17-26	CAPIMQ(I,J,L)	Capacity of project in MGD (punch decimal point).
27-36	CFIMQ(I,J,L)	Fixed costs of project construction in dollars (punch decimal point).
37-46	CØIMQ(I,J,L)	Operating costs per MG of water imported in dollars (punch decimal point).
49	FIX	If project currently exists, set FIX=1; otherwise, leave field blank.

Note: The 'FCTW' header card is not required if there are no treated water import projects to be described. If there are treated water projects, there must be one card for each existing or proposed project. The number of cards will be equal to the total number of projects reported on the Number of Treated Water Import Project cards (appendix B-5).

Appendix B-9. -- Water demand cards (REQUIRED)

Column	Variable Name	Description
Header Card		
1-4	DFWC	'DFWC' -- The remainder of the card may be used to describe the cards that follow.
Demand Cards		
1-4	I	Number of planning region.
5-8	N	Number of planning period.
9-18	DFW(I,N)	Fresh water demand in planning region I during time period N in MGD (punch decimal point).
19-28	PLFW(I,N)	Fresh water loss factor -- fraction (percent) of water lost (punch decimal point).
29-38	DIW(I,N)	Raw water demand in planning region I during planning period N in MGD (punch decimal point).
39-48	PLWW(I,N)	Raw water loss factor -- fraction (percent) of raw water lost (punch decimal point).

Note: Water demand cards are required. There must be NPLAN * NTIME cards; one for each planning region and time period in the model.

Appendix B-10. -- Surface water - ground water interaction parameters (OPTIONAL)

Column	Variable Number	Description
Header Card		
1-4	SWGW	'SWGW' -- The remainder of the card may be used to describe the cards to follow.
Interaction Parameter Cards		
1-4	I	Number of planning unit.
5-8	L	Number of well field.
9-16	PHI(1,I,L)	Values of the response function PHI for the 1st, 2nd, 3rd, ..., and NTIME-th planning periods which relate the recharges from the river to unit pumping of the aquifer at well field L in planning region I (punch decimal point).
17-24	PHI(2,I,L)	
25-32	PHI(3,I,L)	
⋮	⋮	
	PHI(NTIME,I,L)	

NOTE: The 'SWGW' header card is only required if the model includes ground water projects. Each ground water project must have an Interaction Parameter Card. If the model contains more than 9 time periods, the PHI values will overflow onto a second card beginning in the first column. For example, PHI(10,I,L) = columns 1-8, PHI(11,I,L) = columns 9-16, etc.

Appendix B-11. -- Surface water flow requirements cards (REQUIRED)

Column	Variable Number	Description
Header Card		
1-4	SWFL	'SWFL' -- The remainder of the card may be used to describe the cards to follow.
Number of Points Card		
1-4	I	Number of planning region.
5-8	NPX(I)	Number of points at which flow requirements must be met.
Flow Requirements, Card 1		
1-4	I	Number of planning region.
5-8	J	Number of flow requirement point (stream reach).
9-16	QFLØW(I,J)	Sum of natural (unregulated) upland flows which are potentially available for recharging the aquifer in stream reach J.
17-24	RFLØW(I,J)	The flow requirement at the downstream end of stream reach J.
Flow Requirements - Card 2		
1-4	I	Number of planning unit.
5-8	J	Number of flow requirement point (stream reach) under investigation.
9-12	KPDFL(I,J,1)	Inclusive project numbers of diversions whose withdrawals are to be subtracted from QFLØW(I,J).
13-16	KPDFL(I,J,2)	
17-20	KPDFL(I,J,3)	Inclusive project numbers of reservoirs whose withdrawals are to be subtracted from QFLØW(I,J).
21-24	KPDFL(I,J,4)	
25-28	KPDFL(I,J,5)	Inclusive project numbers of ground water fields whose pumping effects on stream flows are to be computed and subtracted from QFLØW(I,J) in order to determine if flow requirement RFLØW(I,J) is met.
29-32	KPDFL(I,J,6)	

Notes: The surface water flow requirements cards are required.

Number of points card -- There must be one of these cards for each planning unit preceding the flow requirement cards even if any or all planning units have zero flow requirement points.

Flow requirements -- These cards occur as pairs for each planning unit and flow requirement point given on the number of points cards. Card 1 given the upland inflows (QFLØW) and the downstream flow requirement (RFLØW). Card 2 gives the inclusive range of diversion, reservoir, and ground water field project numbers to be considered in evaluating the flow requirements for a given point. If only one project is to be considered, enter its number twice, e.g., if reservoir 3 is the only reservoir which affects reach J, then KPDFL(I,J,3)=3 and KPDFL(I,J,4)=3. Care should be taken to number the projects above reach P_i consecutively so that the single range of field project numbers includes only the projects that affect that reach.

Appendix B-12. -- Planning unit and project index cards (OPTIONAL)

Column	Variable Name	Description
Header Card		
1-4	TITLE	'TITL' -- The remainder of the card may be used to describe the cards to follow.
Title Cards		
1-4	I	Number of planning region.
5-8	K	Project type index (see appendix A).
9-12	M	Number of project.
21-80	RDESC	Sixty characters of text which may be used to identify the name and/ or location of projects and planning regions.

Note: These cards are optional and are provided as an aid to the user in identifying which projects, planning regions, etc., were analyzed in any given run of the model. If a planning region is identified, set K=8 and leave M blank.

APPENDIX C. -- Format of MPSX input data cards

APPENDIX C. -- Format of MPSX input data cards

If the MODCOP program is not used to prepare the control card and data cards, these will have to be prepared manually. There are two major types of cards in a MPSX data deck:

1. Indicator cards -- specify the type of data to follow.

2. Data cards -- contain row and/or column names and values of matrix elements.

Data cards have the following format:

Field	Column	Name	Description
1	2-3	Code	Type of row constraint or bounds row vector (left justify, if necessary).
2	5-12	Name 1	Name 1 (name of row or column)
3	15-22	Name 2	Name 2 (usually name of row)
4	25-36	Value 1/2	Value of name 1 or name 2 matrix element
5	40-47	Name 3	Name 3 (usually name of row)
6.	50-61	Value 1/3	Value of name 1 or name 3 matrix element

All names in fields 2, 3, and 5 must begin with an alpha character and may be up to eight characters long. Names may not contain embedded blanks and must be left justified in the field. Values in fields 4 and 6 are 12 characters long, and the decimal point is not fixed. Numbers may also be represented in exponential form (IBM, 1971, p. 188).

The organization of a MPSX data deck is as follows:

1. NAME card -- Always the first card in the deck contains 'NAME' in columns 1-4 and the data deck name (XDATA variable) in columns 15-22.

2. ROWS cards -- Specifies the names to be assigned to the rows of the problem matrix and the types of constraints. The indicator card has "ROWS' in columns 1-4. The data cards are formatted as follows:

Field 1 -- type of constraint code ('N' - change or objective function row; 'G' - greater than or equal to; 'L' - less than or equal to; 'E' - equality).

Field 2 -- row name.

There must be one card for each row name in the matrix.

3. COLUMNS cards -- Specify the names to be assigned columns in the problem matrix and define for each nonzero element in a given column vector the row name and the corresponding column name/row name element value. The indicator card has 'COLUMNS' in columns 1-7. The data cards are formatted as follows:

Field 2 -- Column name
Field 3 -- Row name 1
Field 4 -- Value 1
Field 5 -- Row name 2
Field 6 -- Value 2

Fields 5 and 6 are optional in that their use allows two matrix elements to be stored on one card image instead of just one matrix element.

3. RHS cards -- Specifies the name of the right-hand side constraint vector (or change vectors) and the nonzero elements in that vector. The indicator card has 'RHSb' in columns 1-4. The data cards are formatted as follows:

Field 2 -- RHS name
Field 3 -- Row name 1
Field 4 -- Value 1
Field 5 -- Row name 2
Field 6 -- Value 2.

The use of fields 5 and 6 are optional.

4. RANGES cards -- Used when a row constraint is to represent both a $\geq$ and $\leq$ inequality (see IBM, 1971, p. 193).

5. BOUNDS cards -- Specifies limits to be imposed upon the values which the column variables may assume in the problem. When bounds are not specified the lower bounds are automatically set to zero and the upper bounds are set to + ∞. The indicator card has 'BOUNDS' in columns 1-6. The data cards have the following format:

Field 1 -- Type of bound ('LO'-lower bound; 'UP' - upper bound; 'FX' - fixed value).
Field 2 -- Bound name
Field 3 -- Column name
Field 4 -- Bound value

There should be one card for each nonzero upper and lower bound unless the default values are appropriate.

6. ENDATA card -- The ENDATA card signals the end of the input data and must be the last card in the deck. 'ENDATA' is punched in columns 1-6.

In addition to these control cards a mixed-integer program requires two MARKER cards to signify the beginning and ending of a group of integer column variables. They have the following format:

Field 2 -- Marker card name
Field 3 -- 'MARKER'
Field 4 -- 'INTORG' - signifies the beginning of integer column variables; or 'INTENT' - end of integer column variables.

The two marker cards must have different names. More detailed information on the formats of these cards and other option available to the user of MPSX may be found in MPSX program description (IBM, 1971a and 1971b).

Appendix D. -- Examples of MODCOP input data, MODCOP output tables, and MPSX output for a two-region planning model

```
INIT
YABUCOA9MINCOST RHS01   BND01   YES
  2   6     5.    .07     .08
SYMB
 17  14   5
P01 INS PROJECT INITIATION CONSTRAINTS - DIVERSIONS
P02 IRS   RESERVOIRS
P03 IGS   GW FIELDS
P04 IDS   DESALTING PLANTS
P05 IWP   WATER TREATMENT PLANTS
P06 IUW   RAW WATER IMPORTS
P07 ITW   TREATED WATER IMPORTS
P08 LNS PROJECT LIMITATION CONSTRAINTS - DIVERSIONS
P09 LPS   RESERVOIRS
P10 LGS   GW FIELDS
P11 LDS   DESALTING PLANTS
P12 LWP   WATER TREATMENT PLANTS
P13 LUW   RAW WATER IMPORTS
P14 LTW   TREATED WATER IMPORTS
P15 DFW DEMANDS - FRESH WATER
P16 DTW   TOTAL WATER
P17 DFL   SW FLOW REQUIREMENTS DOWNSTREAM
C01 QNS WATER PRODUCTION - DIVERSIONS
C02 QPS   RESERVOIRS
C03 QGS   GW FIELDS
C04 QDS   DESALTING PLANTS
C05 QWP   WATER TREATMENT PLANTS
C06 QUW   RAW WATER IMPORTS
C07 QTW   TREATED WATER IMPORTS
C08 CNS DESCISION VARIABLES - DIVERSIONS
C09 CPS   RESERVOIRS
C10 CGS   GW FIELDS
C11 CDS   DESALTING PLANTS
C12 CWP   WATER TREATMENT PLANTS
C13 CUW   RAW WATER IMPORTS
C14 CTW   TREATED WATER IMPORTS
NWPP
   1    4    4    9    4    6
   2    0    1    1    0    0
NPWT
   1    2    2
   1    0    0
   2    0    0
NTWT
   1    2    2
   1    0    0
   2    0    0
FCWP
   1    1    1   10       0.20         0.      13.70   1
   1    1    2   10      -1.10    119000.       2.49
   1    1    3   10       3.70    121640.      29.62
```

```
    1    1    4   10        2.00    677000.          1.37
    1    2    1   50        4.95  12930000.          8.30
    1    2    2   50        2.43   3780000.         16.91
    1    2    3   50        7.88   5959000.          5.22
    1    2    4   50        6.45  12952000.          6.73
    1    3    1   30        0.67    108640.         52.46
    1    3    2   30        1.36    116060.         49.40
    1    3    3   30        2.64    292460.         50.52
    1    3    4   30        0.55     29540.         51.39
    1    3    5   30        0.68     76720.         51.20
    1    3    6   30        2.24    163520.         49.59
    1    3    7   30        1.98    120960.         48.22
    1    3    8   30        6.33         0.         50.00    1
    1    3    9   30        0.93    139160.         48.83
    1    4    1   15       20.00  26930000.         92.10
    1    4    2   15       10.00  15240000.        101.00
    1    4    3   15        5.00   9760000         128.00
    1    4    4   15        2.00   4950000         208.00
    1    5    1   20        0.20         0.         50.00    1
    1    5    2   20        8.00   3830000.         45.00
    1    5    3   20        5.00   2780000.         50.00
    1    5    4   20        3.00   1920000.         65.00
    1    5    5   20       10.00   4250000.         41.10
    1    5    6   20        6.0    2660000.         55.00
    2    2    1   50       16.00         0.          5.14    1
    2    3    1   30       18.00         0.         56.00    1
FCRW
    1    2    1   20        8.00   1775000.         48.30
    1    2    2   20        8.00   3088000.          0.00
FCTW
    1    2    1   20        8.00   3390000.          0.00
    1    2    2   20       10.00   3200000.          0.00
DFWC
    1    1        13.5          0.          0.          0.          0.
    1    2        16.3          0.          0.          0.          0.
    1    3        18.0          0.          0.          0.          0.
    1    4        20.0          0.          0.          0.          0.
    1    5        22.8          0.          0.          0.          0.
    1    6        27.5          0.          0.          0.          0.
    2    1         0.0          0.          0.          0.          0.
    2    2         0.0          0.          0.          0.          0.
    2    3         0.0          0.          0.          0.          0.
    2    4         0.0          0.          0.          0.          0.
    2    5         0.0          0.          0.          0.          0.
    2    6         0.0          0.          0.          0.          0.
SWGW
    1    1   .9500   .9950   .9999   .9999   .9999   .9999
    1    2   .9950   .9990   .9995   .9999   .9999   .9999
    1    3   .9950   .9990   .9995   .9999   .9999   .9999
    1    4   .9950   .9990   .9995   .9999   .9999   .9999
    1    5   .9950   .9990   .9995   .9999   .9999   .9999
    1    6   .9950   .9990   .9995   .9999   .9999   .9999
    1    7   .9950   .9990   .9995   .9999   .9999   .9999
    1    8   .9950   .9990   .9995   .9999   .9999   .9999
    1    9   .9500   .9950   .9999   .9999   .9999   .9999
    2    1   .0000   .0000   .0000   .0000   .0000   .0000
SWFL
    1    1
    2    0
    1    1    41.7    14.3
```

```
   1    1    1   4   1   4   1   9
TITL         OPTIONAL PROJECT TITLES
   1    8              YABUCOA PLANNING REGION
   1    1    1         QUEBRADA AGUAS LARGAS
   1    1    2         Q. GUAYABO
   1    1    3         RIO GUAYANES -- LOWER SITE
   1    1    4         RIO GUAYANES -- UPPER SITE
   1    2    1         GUAYABO (RESERVOIR 1)
   1    2    2         ARENAS (RESERVOIR 15)
   1    2    3         GUAYANES (RESERVOIR 14)
   1    2    4         LIMONES (RESERVOIR 6)
   1    3    1         YABUCOA VALLEY WELL FIELDS 1-9
   1    4    1         YABUCOA DESALINIZATION PLANT #1-4
   1    5    1         YABUCOA WTP -- EXISTING PLANT
   1    5    2         NEW YABUCOA WTP -- A
   1    5    3         NEW YABUCOA WTP -- B
   1    5    4         NEW YABUCOA WTP -- C
   1    5    5         NEW YABUCOA WTP -- D
   2    8              REST OF THE "WORLD"
   2    2    1         DUMMY RESERVOIR ASSUMED TO EXIST
   2    3    1         DUMMY GROUNDWATER FIELD ASSUMED TO EXIST
   1    6    1         RAW WATER IMPORT FROM SAN LORENZO VIA CAYAGUS RES.
   1    6    2         RAW WATER IMPORT FROM MAUNABO VIA RIO MAUNABO RES.
   1    7    1         TREATED WATER IMPORT FROM MAUNABO (ASSUMMED GW FIELD(
   1    7    2         TREATED WATER IMPORT FROM HUMACOA (ASSUMMED GW FIELD(
/*
/*EOF
```

```
PUERTO RICO WATER RESOURCES DEVELOPMENT PLANNING MODEL
MODEL DEFINITION AND CONTROL PROGRAM (MODCOP) - VERSION 3   5/11/73

SUMMARY OF WATER RESOURCES PLANNING MODEL DATA

PROBLEM NAME              = YABUCOA1
OBJECTIVE FUNCTION NAME   = MINCOST
RHS VECTOR NAME           = RHS01
BOUNDS VECTOR NAME        = BND01

NUMBER OF PLANNING UNITS  =   2
NUMBER OF TIME PERIODS    =   5
LENGTH OF TIME PERIOD     =  5.0000
ANNUAL INTEREST RATE      =  0.0700
PERIOD INTEREST RATE      =  0.4025
AMORTIZATION INTEREST RATE=  0.0800


LIST OF ROW SYMBOLS

RSYMB( 1) = INS   PROJECT INITIATION CONSTRAINTS - DIVERSIONS
RSYMB( 2) = IRS     RESERVOIRS
RSYMB( 3) = IGS     GW FIELDS
RSYMB( 4) = IDS     DESALTING PLANTS
RSYMB( 5) = IWP     WATER TREATMENT PLANTS
RSYMB( 6) = IUW     RAW WATER IMPORTS
RSYMB( 7) = ITW     TREATED WATER IMPORTS
RSYMB( 8) = LNS   PROJECT LIMITATION CONSTRAINTS - DIVERSIONS
RSYMB( 9) = LRS     RESERVOIRS
RSYMB(10) = LGS     GW FIELDS
RSYMB(11) = LDS     DESALTING PLANTS
RSYMB(12) = LWP     WATER TREATMENT PLANTS
RSYMB(13) = LUW     RAW WATER IMPORTS
RSYMB(14) = LTW     TREATED WATER IMPORTS
RSYMB(15) = DFW   DEMANDS - FRESH WATER
RSYMB(16) = DTW     TOTAL WATER
RSYMB(17) = DFL     SW FLOW REQUIREMENTS DOWNSTREAM
CSYMB( 1) = QNS   WATER PRODUCTION - DIVERSIONS
CSYMB( 2) = QRS     RESERVOIRS
CSYMB( 3) = QGS     GW FIELDS
CSYMB( 4) = QDS     DESALTING PLANTS
CSYMB( 5) = QWP     WATER TREATMENT PLANTS
CSYMB( 6) = QUW     RAW WATER IMPORTS
CSYMB( 7) = QTW     TREATED WATER IMPORTS
CSYMB( 8) = CNS   DESCISION VARIABLES - DIVERSIONS
CSYMB( 9) = CRS     RESERVOIRS
CSYMB(10) = CGS     GW FIELDS
CSYMB(11) = CDS     DESALTING PLANTS
CSYMB(12) = CWP     WATER TREATMENT PLANTS
CSYMB(13) = CUW     RAW WATER IMPORTS
CSYMB(14) = CTW     TREATED WATER IMPORTS
```

SUMMARY OF NUMBER OF PROJECTS IN EACH PLANNING UNIT BY TYPE (NON-TRANSPORT)

TYPE	A	B
	PLANNING UNIT ID	
DIVERSION	4	0
RESERVOIR	4	1
GW STORAGE	9	1
DESALTING	4	0
W T PLANT	6	0

SUMMARY OF NUMBER OF RAW WATER IMPORT PROJECTS IN EACH PLANNING UNIT

IMPORT TO PLANNING UNIT	A	B
	FROM PLANNING UNIT	
UNIT = A	0	2
UNIT = B	0	0

SUMMARY OF NUMBER OF TREATED WATER IMPORT PROJECTS IN EACH PLANNING UNIT

IMPORT TO PLANNING UNIT	A	B
	FROM PLANNING UNIT	
UNIT = A	0	2
UNIT = B	0	0

SUMMARY OF PROJECT PARAMETERS USED IN PR-WR PLANNING MODEL
RAW WATER IMPORT PROJECT PARAMETERS

PLANNING UNIT TO	PLANNING UNIT FROM	PROJECT LIFE (YRS)	CAPACITY (MGD)	CAPACITY TIME PERIOD (5.0 YRS)	FIXED COSTS	ANNUAL FIXED COSTS AT 8.00 PERCENT	OPERATING COSTS PER MG	EXISTING
A	B- 1	20	8.00	14600.	1775000.	180788.	48.30	NO
A	B- 2	20	8.00	14600.	3088000.	314520.	0.0	NO

SUMMARY OF PROJECT PARAMETERS USED IN PR-WR PLANNING MODEL
TREATED WATER IMPORT PROJECT PARAMETERS

PLANNING UNIT TO	PLANNING UNIT FROM	PROJECT LIFE (YRS)	CAPACITY (MGD)	CAPACITY TIME PERIOD (5.0 YRS)	FIXED COSTS	ANNUAL FIXED COSTS AT 8.00 PERCENT	OPERATING COSTS PER MG	EXISTING
A	B- 1	20	8.00	14600.	3390000.	345280.	0.0	NO
A	B- 2	20	10.00	18250.	3200000.	325928.	0.0	NO

SUMMARY OF PROJECT PARAMETERS USED IN PR-WR PLANNING MODEL
WATER PRODUCTION PROJECT PARAMETERS

PLANNING UNIT	PROJECT TYPE	PROJECT LIFE (YRS)	SAFE YIELD (MGD)	YIELD OVER TIME PERIOD (5.0 YRS)	FIXED COSTS	ANNUAL FIXED COSTS AT 8.00 PERCENT	OPERATING COSTS PER MG	EXIST-ING	TOTAL SUPPLY (MG)
A	DIVERSION - 1	10	0.20	365.	0.	0.	13.70	YES	
A	DIVERSION - 2	10	1.10	2007.	119000.	17735.	2.49	NO	
A	DIVERSION - 3	10	3.70	6752.	121640.	18128.	29.62	NO	
A	DIVERSION - 4	10	2.00	3650.	677000.	100893.	1.37	NO	
A	RESERVOIR - 1	50	4.95	9034.	12990000.	1061839.	8.30	NO	
A	RESERVOIR - 2	50	2.43	4435.	3780000.	308988.	16.91	NO	
A	RESERVOIR - 3	50	7.88	14381.	5959000.	487105.	5.22	NO	
A	RESERVOIR - 4	50	6.45	11771.	12952000.	1058733.	6.73	NO	
A	GW STORAGE- 1	30	1.01	1843.	108640.	9650.	52.46	NO	
A	GW STORAGE- 2	30	2.03	3705.	116060.	10309.	49.40	NO	
A	GW STORAGE- 3	30	3.96	7227.	292460.	25979.	50.52	NO	
A	GW STORAGE- 4	30	0.82	1496.	29540.	2624.	51.39	NO	
A	GW STORAGE- 5	30	1.02	1861.	76720.	6815.	51.20	NO	
A	GW STORAGE- 6	30	3.37	6150.	163520.	14525.	49.59	NO	
A	GW STORAGE- 7	30	2.97	5420.	120960.	10745.	48.22	NO	
A	GW STORAGE- 8	30	6.33	11552.	0.	0.	50.00	YES	
A	GW STORAGE- 9	30	1.40	2555.	139160.	12361.	48.83	NO	
A	DESALTING - 1	15	20.00	36500.	26930000.	3146230.	92.10	NO	
A	DESALTING - 2	15	10.00	18250.	15240000.	1780488.	101.00	NO	
A	DESALTING - 3	15	5.00	9125.	97600000.	11402601.	128.00	NO	
A	DESALTING - 4	15	2.00	3650.	49500000.	5783081.	208.00	NO	
A	W T PLANT - 1	20	0.20	365.	0.	0.	50.00	YES	
A	W T PLANT - 2	20	8.00	14600.	3830000.	390095.	45.00	NO	
A	W T PLANT - 3	20	5.00	9125.	2780000.	283150.	50.00	NO	
A	W T PLANT - 4	20	3.00	5475.	1920000.	195557.	65.00	NO	
A	W T PLANT - 5	20	10.00	18250.	4250000.	432873.	41.10	NO	
A	W T PLANT - 6	20	6.00	10950.	2660000.	270928.	55.00	NO	161731.
B	RESERVOIR - 1	50	16.00	29200.	0.	0.	5.14	YES	
B	GW STORAGE- 1	30	18.00	32850.	0.	0.	56.00	YES	62050.

SUMMARY OF WATER DEMANDS USED IN PR-WR PLANNING MODEL

PLANNING UNIT	TIME PERIOD	FRESH WATER DEMAND (MGD)	FRESH WATER USE FACTOR	INTERMEDIATE QUALITY DEMAND (MGD)	INTERMEDIATE USE FACTOR
A	1	6.50	0.0	0.0	0.0
A	2	11.50	0.0	0.0	0.0
A	3	14.80	0.0	0.0	0.0
A	4	20.00	0.0	0.0	0.0
A	5	25.20	0.0	0.0	0.0
B	1	0.0	0.0	0.0	0.0
B	2	0.0	0.0	0.0	0.0
B	3	0.0	0.0	0.0	0.0
B	4	0.0	0.0	0.0	0.0
B	5	0.0	0.0	0.0	0.0

PLANNING UNIT	TIME PERIOD	FRESH WATER DEMAND (MG)	FRESH WATER USE FACTOR	INTERMEDIATE QUALITY DEMAND (MG)	INTERMEDIATE USE FACTOR	TOTAL ADJUSTED DEMAND (MG)
A	1	11862.50	0.0	0.0	0.0	11862.50
A	2	20987.50	0.0	0.0	0.0	20987.50
A	3	27010.00	0.0	0.0	0.0	27010.00
A	4	36500.00	0.0	0.0	0.0	36500.00
A	5	45989.99	0.0	0.0	0.0	45989.99
B	1	0.0	0.0	0.0	0.0	0.0
B	2	0.0	0.0	0.0	0.0	0.0
B	3	0.0	0.0	0.0	0.0	0.0
B	4	0.0	0.0	0.0	0.0	0.0
B	5	0.0	0.0	0.0	0.0	0.0

SUMMARY OF SW-GW INTERACTION COEFFICIENTS

PLANNING TIME UNIT	PERIOD	WELL FIELD NUMBER 1	2	3	4	5	6	7	8	9
1	1	0.95000	0.99500	0.99500	0.99500	0.99500	0.99500	0.99500	0.99500	0.95000
	2	0.99500	0.99900	0.99900	0.99900	0.99900	0.99900	0.99900	0.99900	0.99500
	3	0.99990	0.99950	0.99950	0.99950	0.99950	0.99950	0.99950	0.99950	0.99990
	4	0.99990	0.99990	0.99990	0.99990	0.99990	0.99990	0.99990	0.99990	0.99990
	5	0.99990	0.99990	0.99990	0.99990	0.99990	0.99990	0.99990	0.99990	0.99990

PLANNING TIME UNIT	PERIOD	1
2	1	0.0
	2	0.0
	3	0.0
	4	0.0
	5	0.0

SUMMARY OF SW WITHDRAWALS DUE TO GW PUMPING

PLANNING TIME UNIT	PERIOD	WELL FIELD NUMBER 1	2	3	4	5	6	7	8	9
1.	1	0.95000	0.99500	0.99500	0.99500	0.99500	0.99500	0.99500	0.99500	0.95000
	2	0.04500	0.00400	0.00400	0.00400	0.00400	0.00400	0.00400	0.00400	0.04500
	3	0.00490	0.00050	0.00050	0.00050	0.00050	0.00050	0.00050	0.00050	0.00490
	4	0.0	0.00040	0.00040	0.00040	0.00040	0.00040	0.00040	0.00040	0.0
	5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

PLANNING TIME UNIT	PERIOD	1
2	1	0.0
	2	0.0
	3	0.0
	4	0.0
	5	0.0

SUMMARY OF NATURAL INFLOWS AND REQUIRED OUTFLOWS

PLANNING UNIT	POINT NUMBER	NATURAL FLOWS		REQUIRED FLOWS			
1	1	87.20		14.30			
1	1	1	4	1	4	1	9

SUMMARY OF NATURAL INFLOWS AND REQUIRED OUTFLOWS

PLANNING UNIT	POINT NUMBER	NATURAL FLOWS	REQUIRED FLOWS
1	1	159140.	26097.

PLANNING UNIT	POINT NUMBER	NATURAL FLOWS	REQUIRED FLOWS
1	1	159140.	26097.

MPSX PROGRAM

```
MPSX-PTF12     CONTROL PROGRAM COMPILER.  MPSX  RELEASE 1  MOD LEVEL 3

      0001                    PROGRAM
      0002                    INITIALZ
      0092                    TITLE('PRMODEL-VER3-YABUCOA1')
      0093                    MOVE(XPBNAME,'YABUCOA1')
      0094                    MOVE(XDATA,'YABUCOA1')
      0095                    CONVERT
      0096                    SETUP('BOUND','BND01')
      0097                    MOVE(XRHS,'RHS01')
      0098                    MOVE(XOBJ,'MINCOST')
      0099                    OPTIMIZE
      0401                    SOLUTION
      0402                    OPTIMIX('COST',0.,10.0,0)
      0498                    PROBLEMS('PROBFILE')
      0499                    IF(OPTMRC.NE.0,A)
      0500                    RANGE
      0501          A         EXIT
      0502                    PEND
```

This MPSX program will set up a problem (XPBNAME) called 'YABUCOA1' on the problem file. Input data is read from a data set (XDATA) called 'YABUCOA1.' After converting the input data and assigning names to the bounds (BOUND), right-hand side (XRHS) and objective function (XOBJ), the program obtains a continuous solution and prints it out. Next, the program searches for an integer optimum (a time limit of 10 minutes is set for this program). Finally, if an optimum integer solution is obtained, the post optimal procedure range is performed. Otherwise, the program ends.

INTEGER NODES

NODE	123	130	229	340	517	538
FUNCTIONAL	106593593.2	106584587.2	55656932.66	17668390.13	2942200.361	2931597.035
ESTIMATION	INTEGER	INTEGER	INTEGER	INTEGER	INTEGER	INTEGER
365= CNSA102	.	.	.	.	.	.
366= CNSA103	.	.	.	.	.	.
367= CNSA104	.	.	.	.	.	.
368= CNSA202	.	.	.	.	.	.
369= CNSA203	.	.	.	.	.	.
370= CNSA204	.	.	.	.	.	.
371= CNSA302	.	.	.	.	.	.
372= CNSA303	.	.	.	.	.	.
373= CNSA304	.	.	.	.	.	.
374= CNSA402	.	.	.	.	.	.
375= CNSA403	.	.	.	.	.	.
376= CNSA404	.	.	.	.	.	.
377= CNSA502	.	.	.	.	.	.
378= CNSA503	.	.	1.0000	1.0000	1.0000	1.0000
379= CNSA504	.	.	.	.	.	.
380= CRSA101	.	.	.	.	.	.
381= CRSA102	.	.	.	.	.	.
382= CRSA103	.	.	.	.	.	.
383= CRSA104	.	.	.	.	.	.
384= CRSA201	.	.	.	.	.	.
385= CRSA202	.	.	.	.	.	.
386= CRSA203	.	.	.	.	.	.
387= CRSA204	.	.	.	.	.	.
388= CRSA301	.	.	.	.	.	.
389= CRSA302	.	.	.	.	.	.
390= CRSA303	.	.	.	.	.	.
391= CRSA304	.	.	.	.	.	.
392= CRSA401	.	.	.	.	.	.
393= CRSA402	.	.	.	.	.	.
394= CRSA403	.	.	.	.	.	.
395= CRSA404	.	.	.	.	.	.
396= CRSA501	.	.	.	.	.	.
397= CRSA502	.	.	.	.	.	.
398= CRSA503	.	.	.	.	.	.
399= CRSA504	.	.	.	.	.	.
400= CGSA101	.	.	.	.	.	.
401= CGSA102	.	.	.	.	.	.
402= CGSA103	.	.	.	.	.	.

403= CGSA104	.	.	.	.	.	.
404= CGSA105	.	.	1.0000	.	.	.
405= CGSA106	.	.	.	.	.	.
406= CGSA107	.	.	.	.	.	.
407= CGSA109	.	.	.	.	.	.
408= CGSA201	.	.	.	.	.	.
409= CGSA202	1.0000	1.0000	.	1.0000	1.0000	1.0000
410= CGSA203	.	.	.	.	.	.
411= CGSA204	.	.	1.0000	.	.	.
412= CGSA205	.	.	.	.	.	.
413= CGSA206	.	.	1.0000	.	.	.
414= CGSA207	1.0000	1.0000	.	1.0000	1.0000	1.0000
415= CGSA209	.	.	.	.	.	.
416= CGSA301	.	.	.	.	.	.
417= CGSA302	.	.	.	.	.	.
418= CGSA303	.	.	.	.	.	.
419= CGSA304	.	.	.	.	.	.
420= CGSA305	.	.	.	.	.	.
421= CGSA306	1.0000	1.0000	.	1.0000	1.0000	1.0000
422= CGSA307	.	.	1.0000	.	.	.
423= CGSA309	.	.	.	.	.	.
424= CGSA401	1.0000	.	.	.	1.0000	.
425= CGSA402	.	.	.	.	.	.
426= CGSA403	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
427= CGSA404	.	.	.	1.0000	.	1.0000
428= CGSA405	1.0000	1.0000	.	.	1.0000	1.0000
429= CGSA406	.	.	.	.	.	.
430= CGSA407	.	.	.	.	.	.
431= CGSA409	.	.	1.0000	.	.	.
432= CGSA501	.	1.0000	1.0000	1.0000	1.0000	1.0000
433= CGSA502	.	.	1.0000	.	.	.
434= CGSA503	.	.	.	.	.	.
435= CGSA504	1.0000	1.0000	.	.	1.0000	.
436= CGSA505	.	.	.	1.0000	.	.
437= CGSA506	.	.	.	.	.	.
438= CGSA507	.	.	.	.	.	.
439= CGSA509	1.0000	1.0000	.	1.0000	1.0000	1.0000
440= CDSA101	.	.	.	.	.	.
441= CDSA102	.	.	.	.	.	.
442= CDSA103	1.0000	1.0000	.	.	.	.
443= CDSA104	.	.	1.0000	.	.	.
444= CDSA201	.	.	.	.	.	.
445= CDSA202	.	.	.	.	.	.
446= CDSA203	.	.	.	.	.	.
447= CDSA204	.	.	.	.	.	.
448= CDSA301	.	.	.	.	.	.
449= CDSA302	.	.	.	.	.	.
450= CDSA303	.	.	.	.	.	.
451= CDSA304	.	.	.	.	.	.
452= CDSA401	.	.	.	.	.	.
453= CDSA402	.	.	.	.	.	.
454= CDSA403	.	.	.	.	.	.
455= CDSA404	.	.	.	1.0000	.	.
456= CDSA501	.	.	.	.	.	.

D15

457= CDSA502	.	.	.	.	.	.	.
458= CDSA503	.	.	.	.	.	.	.
459= CDSA504	.	.	.	.	.	.	.
460= CWPA102	.	.	.	.	.	.	.
461= CWPA103	.	.	.	.	.	.	.
462= CWPA104	.	.	.	.	.	.	.
463= CWPA105	.	.	.	.	.	.	.
464= CWPA106	.	.	.	.	.	.	.
465= CWPA202	.	.	.	.	.	.	.
466= CWPA203	.	.	.	.	.	.	.
467= CWPA204	.	.	.	.	.	.	.
468= CWPA205	.	.	.	.	.	.	.
469= CWPA206	.	.	.	.	.	.	.
470= CWPA302	.	.	.	.	.	.	.
471= CWPA303	.	.	.	.	.	.	.
472= CWPA304	.	.	.	.	.	.	.
473= CWPA305	.	.	.	.	.	.	.
474= CWPA306	.	.	.	.	.	.	.
475= CWPA402	.	.	.	.	.	.	.
476= CWPA403	.	.	.	.	.	.	.
477= CWPA404	.	.	.	.	.	.	.
478= CWPA405	.	.	.	.	.	.	.
479= CWPA406	.	.	.	.	.	.	.
480= CWPA502	.	.	.	.	.	.	.
481= CWPA503	.	.	.	.	.	.	.
482= CWPA504	.	.	1.0000	1.0000	1.0000	1.0000	
483= CWPA505	.	.	.	.	.	.	.
484= CWPA506	.	.	.	.	.	.	.
485= CUWAB101	.	.	.	.	.	.	.
486= CUWAB102	.	.	.	.	.	.	.
487= CUWAB201	.	.	.	.	.	.	.
488= CUWAB202	.	.	.	.	.	.	.
489= CUWAB301	.	.	.	.	.	.	.
490= CUWAB302	.	.	.	.	.	.	.
491= CUWAB401	.	.	.	.	.	.	.
492= CUWAB402	.	.	.	.	.	.	.
493= CUWAB501	.	.	.	.	.	.	.
494= CUWAB502	.	.	.	.	.	.	.
495= CTWAB101	.	.	.	.	.	.	.
496= CTWAB102	.	.	.	.	.	.	.
497= CTWAB201	.	.	.	.	.	.	.
498= CTWAB202	.	.	.	.	.	.	.
499= CTWAB301	.	.	.	.	.	.	.
500= CTWAB302	.	.	.	.	.	.	.
501= CTWAB401	.	.	.	.	.	.	.
502= CTWAB402	.	.	.	.	.	.	.
503= CTWAB501	.	.	.	.	.	.	.
504= CTWAB502	.	.	.	.	.	.	.

MPSX - MIXED INTEGER PROGRAM - RELEASE 1 MOD LEVEL 3

PROBLEM NAME = YABUCOA1 DATE = 73/151

.....PROBLEM STATISTICS......

ROWS	199
COLUMNS	305
VARIABLES	504
INTEGER VARIABLES	140
ELEMENTS	1626
DENSITY	1.62

...COMPUTATIONAL ELEMENTS....

FUNCTIONAL (MIN)	MINCOST
RESTRAINTS	RHS01
BOUNDS	BND01

.........ENVIRONMENT.........

C.P.U			
CORE ALLOCATED			165672
SCRATCH	ON	......DISK	2314
MATRIX	ON	......DISK	2314
ETA	ON	......DISK	2314
MIXWORK	ON	......DISK	2314
PROBFILE	ON	......DISK	2314

	TIME SINCE MIXSTART	ITERATION NO. SINCE SETUP	NODE NO.	FUNCTIONAL VALUE	STRATEGY
CONTINUOUS OPTIMUM		586	1	2735863.3439	
FIRST INTEGER SOLUTION	0.88	1355	123	106593593.211	
OPTIMAL INTEGER SOLUTION	3.67	3725	538	2931597.0351	
OPTIMALITY PROVED	3.81	3808	546		
TIME OF SEARCH	3.81	3808	546		'COST'

NUMBER OF INTEGER VARIABLES NOT INTEGER AT CONTINUOUS OPTIMUM = 9

NUMBER OF INTEGER SOLUTIONS FOUND = 6

BRANCHES ABANDONED WHILE COMPUTING = 49

Appendix E. -- Source listing of MODCOP

(version 3)

```
C  * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
C  *                                                                     *
C  *  PUERTO RICO WATER RESOURCES DEVELOPMENT PLANNING MODEL             *
C  *  MODEL DEFINITION AND CONTROL PROGRAM(MODCOP) - VERSION 3           *
C  *                                                                     *
C  *     DATE-- 5/11/73                                                  *
C  *     FOR FURTHER INFORMATION CONTACT:                                *
C  *       SYSTEMS ANALYSIS GROUP                                        *
C  *       WATER RESOURCES DIVISION                                      *
C  *       U. S. GEOLOGICAL SURVEY                                       *
C  *       WASHINGTON, D.C. 20244                                        *
C  *       (202)-343-3660                                                *
C  *                                                                     *
C  * MAIN PROGRAM FOR PUERTO RICO MATRIX GENERATOR                       *
C  *                                                                     *
C  *     THIS PROGRAM PREPARES CONTROL CARDS AND DATA FOR INPUT TO       *
C  *     IBM'S MATHEMATICAL PROGRAMMING SYSTEM--EXTENDED (MPSX).         *
C  *     THE PROBLEM MATRIX IS FORMULATED FOR THE PUERTO RICO            *
C  *     WATER RESOURCES REGIONAL PLANNING MODEL (VERSION 3).            *
C  *                                                                     *
C  * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
C
      CALL DATA
      CALL PR
      CALL EXIT
      STOP
      END
```

```
0001            SUBROUTINE PR
          C
          C  * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
          C  *                                                                 *
          C  *   THIS SUBROUNTINE SETS UP DATA IN PROPER FORMAT FOR MPSX.      *
          C  *   THE PUERTO RICO WATER RESOURCES PLANNING MODEL HAS THE FOLLOWING *
          C  *   SECTIONS:                                                     *
          C  *                                                                 *
          C  *     A. 'NAME' OF PROBLEM                                        *
          C  *     B. 'ROWS' CARD - BEGINNING OF ROW SECTION                   *
          C  *       1. NAME OF OBJECTIVE FUNCTION                             *
          C  *       2. INITIATION OF PROJECT CONSTRAINT - I..                 *
          C  *       3. PROJECT LIMITATION CONSTRAINT - L..                    *
          C  *       4. FRESHWATER DEMANDS - DFW                               *
          C  *       5. TOTAL WATER DEMANDS - DTW                              *
          C  *       6. REQUIRED DOWNSTREAM FLOWS (SW-GW INTERACT.)  - DFL     *
          C  *                                                                 *
          C  * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
          C
0002            CONTINUE
          C
          C  * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
          C  *                                                                 *
          C  *     C. 'COLUMNS' CARD - COLUMNS SECTION                         *
          C  *       1. CONTINUOUS VARIABLE SECTION                            *
          C  *         I. WATER PRODUCED FROM STORAGE SYSTEMS AND WT PLANTS - Q.. *
          C  *        II. WATER IMPORTED FROM OTHER PLANNING UNITS             *
          C  *          II-A. RAW WATER - QU.                                  *
          C  *          II-B. TREATED WATER - QW.                              *
          C  *                                                                 *
          C  * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
          C
0003            CONTINUE
          C
          C  * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
          C  *                                                                 *
          C  *       2. INTEGER VARIABLE SECTION                               *
          C  *         I. 'INTORG' MARKER CARD                                 *
          C  *        II. DECISION VARIABLE TO BUILD STORAGE PROJECT - C..     *
          C  *       III. DECISION VARIABLE TO BUILD IMPORT PROJECT - CIS      *
          C  *        IV. 'INTEND' MARKER CARD                                 *
          C  *     D. RIGHT-HAND SIDE SECTION                                  *
          C  *       1. 'RHS' CARD                                             *
          C  *       2. LIMITATION ON INITIATION OF PROJECTS                   *
          C  *       3. FRESH WATER DEMANDS - DFW                              *
          C  *       4. TOTAL WATER DEMANDS - DTW                              *
          C  *     E. BOUNDS SECTION                                           *
          C  *       1. 'BOUNDS' CARD                                          *
          C  *       2. BOUNDS ON WITHDRAWAL FROM STORAGE                      *
          C  *       3. BOUNDS ON TRANSPORT WATER                              *
          C  *       4. BOUNDS ON DECISION VARIABLES FOR STORAGE PROJEGTS      *
          C  *       5. BOUNDS ON IMPORT PROJECT DECISION VARIABLES            *
          C  *     F. END DATA SECTION - 'ENDATA' CARD                         *
          C  *                                                                 *
          C  * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
```

```
              C
0004                REAL*8 PNAME,OBNAME,RHNAME,BNAME
0005                LOGICAL RFLAG
0006                LOGICAL FXFLAG( 5, 8,10),IMPFIX( 8, 8,10),IMQFIX( 8, 8,10)
0007                LOGICAL*1 S(30)/'A','B','C','D','E','F','G','H','I','J','K','L',
                   * 'M','N','O','P','Q','R','S','T','U','V','W','X','Y','Z','1','2',
                   * '3','4'/
              C
              C  LABELLED COMMON BLOCKS
              C     SEE SUBROUTINE DATA FOR VARIABLE DEFINITION
              C
0008                COMMON/C1/ NPLAN,NTIME,NPROJ( 5, 8),NPIMP( 8, 8),NPIMQ( 8, 8),NP
0009                COMMON/C2/ NRSYMB,RSYMB(25),NCSYMB,CSYMB(25)
0010                COMMON/C3/ CF( 5, 8,10),CO( 5, 8,10),CFIMP( 8, 8,10),
                   1 CFIMQ( 8, 8,10),COIMP( 8, 8,10),COIMQ( 8, 8,10),AFC( 5, 8,10),
                   2 AFCIMP( 8, 8,10),AFCIMQ( 8, 8,10)
0011                COMMON/C4/ PLFW( 8,10), PLIW( 8,10)
0012                COMMON/C5/ PHI(10, 8,10), F(10, 8,10)
0013                COMMON/C6/ TIME,R,RAM
0014                COMMON/C7/ CAP( 5, 8,10), CAPIMP( 8, 8,10),CAPIMQ( 8, 8,10)
0015                COMMON/C8/ DFW( 8,10),DIW( 8,10),DEX( 8,10),TAD( 8,10)
0016                COMMON/C8A/OFLOW( 8,10), RFLOW( 8,10)
0017                COMMON/C9/ NL( 5, 8,10),NLIMP( 8, 8,10),NLIMQ( 8, 8,10)
0018                COMMON/C10/ YLD( 5, 8,10),YLDIMP( 8, 8,10), YLDIMQ( 8, 8,10)
0019                COMMON/C11/ RFLAG
0020                COMMON/C12/ FXFLAG,IMPFIX,IMQFIX
0021                COMMON/C13/ RPV
0022                COMMON/C14/ PNAME,OBNAME,RHNAME,BNAME
0023                COMMON/C15/KPDFL(8,5,6)
0024                COMMON/C16/ NPX(8)
              C
              C  %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
              C  %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
              C
              C SET UP NAME, ROW AND OBJECTIVE FUNCTION
              C     SECTIONS A, B, AND B-1
              C
0025                WRITE(6,1010)
0026           1010 FORMAT('1')
0027                IF (RFLAG) WRITE(6,1015) PNAME,OBNAME
0028           1015 FORMAT(1X,'NAME',10X,A8/1X,'ROWS'/1X,'N',2X,A8)
0029                WRITE(11,1020) PNAME,OBNAME
0030           1020 FORMAT('NAME',10X,A8/'ROWS'/1X,'N',2X,A8)
              C
              C CYCLE CONSTRAINTS BY PLANNING UNIT
              C
              C  %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
              C
0031                DO 100 I=1,NPLAN
              C
              C  %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
              C
              C  INITIALIZE NUMBER OF FLOW REQUIREMENT POINTS
              C
0032                NPXX=NPX(I)
              C
```

```
            C     PROJECT INITIATION CONTRAINS FOR STORAGE SYSTEMS AND
            C   DESALINIZATION PLANTS
            C     SECTION B-2
            C
0033              DO 10 K=1,NP
0034              DO 10 N=1,NTIME
0035              NPJ=NPROJ(K,I)
0036              IF(NPJ.EQ.0) GO TO 10
0037              DO 10 M=1,NPJ
0038              IF(FXFLAG(K,I,M)) GO TO 10
0039              MD1=M/10
0040              MD2=M-MD1*10
0041              IF(RFLAG) WRITE(6,1030) RSYMB(K),S(I),N,MD1,MD2
0042              WRITE(11,1030) RSYMB(K),S(I),N,MD1,MD2
0043         1030 FORMAT(1X,'G',2X,A3,A1,3I1)
0044           10 CONTINUE
            C
            C    PROJECT INITIATION CONSTRAINTS FOR RAW WATER IMPORTS
            C
0045              DO 20 J=1,NPLAN
0046              IF(J.EQ.I) GO TO 20
0047              DO 20 N=1,NTIME
0048              NPJ=NPIMP(I,J)
0049              IF(NPJ.EQ.0) GO TO 20
0050              DO 20 M=1,NPJ
0051              IF(IMPFIX(I,J,M)) GO TO 20
0052              MD1=M/10
0053              MD2=M-MD1*10
0054              IF(RFLAG) WRITE( 6,1040) RSYMB(6),S(I),S(J),N,MD1,MD2
0055              WRITE(11,1040) RSYMB(6),S(I),S(J),N,MD1,MD2
0056         1040 FORMAT(1X,'G',2X,A3,2A1,3I1)
0057           20 CONTINUE
            C
            C    PROJECT INITIATION CONSTRAINTS FOR TREATED WATER IMPORTS
            C
0058              DO 25 J=1,NPLAN
0059              IF(J.EQ.I) GO TO 25
0060              DO 25 N=1,NTIME
0061              NPJ=NPIMQ(I,J)
0062              IF(NPJ.EQ.0) GO TO 25
0063              DO 25 M=1,NPJ
0064              IF(IMQFIX(I,J,M)) GO TO 25
0065              MD1=M/10
0066              MD2=M-MD1*10
0067              IF(RFLAG) WRITE( 6,1040) RSYMB(7),S(I),S(J),N,MD1,MD2
0068              WRITE(11,1040) RSYMB(7),S(I),S(J),N,MD1,MD2
0069           25 CONTINUE
            C
            C   %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
            C
            C     PROJECT LIMITATION CONTRAINS FOR STORAGE SYSTEMS AND
            C     DESALINIZATION SYSTEMS INCLUDING WATER TREATMENT PLANTS
            C     SECTION B-3
            C
0070              DO 30 K=1,NP
0071              NPJ=NPROJ(K,I)
```

```
0072          IF(NPJ.EQ.0) GO TO 30
0073          DO 30 M=1,NPJ
0074          IF(FXFLAG(K,I,M)) GO TO 30
0075          MD1=M/10
0076          MD2=M-MD1*10
0077          IF(RFLAG) WRITE( 6,1050) RSYMB(K+7),S(I),MD1,MD2
0078          WRITE(11,1050) RSYMB(K+7),S(I),MD1,MD2
0079     1050 FORMAT(1X,'L',2X,A3,A1,2I1)
0080       30 CONTINUE
        C
        C   PROJECT LIMITATION CONSTRAINTS FOR RAW WATER IMPORTS
        C
0081          DC 40 J=1,NPLAN
0082          IF(J.EQ.I) GO TO 40
0083          NPJ=NPIMP(I,J)
0084          IF(NPJ.EQ.0) GO TO 40
0085          DO 40 M=1,NPJ
0086          IF(IMPFIX(I,J,M)) GO TO 40
0087          MD1=M/10
0088          MD2=M-MD1*10
0089          IF(RFLAG) WRITE( 6,1060) RSYMB(13),S(I),S(J),MD1,MD2
0090          WRITE(11,1060) RSYMB(13),S(I),S(J),MD1,MD2
0091     1060 FORMAT(1X,'L',2X,A3,A1,A1,2I1)
0092       40 CONTINUE
        C
        C   PROJECT LIMITATION CONSTRAINTS FOR TREATED WATER IMPORTS
        C
0093          DO 45 J=1,NPLAN
0094          IF(J.EQ.I) GO TO 45
0095          NPJ=NPIMQ(I,J)
0096          IF(NPJ.EQ.0) GO TO 45
0097          DO 45 M=1,NPJ
0098          IF(IMQFIX(I,J,M)) GO TO 45
0099          MD1=M/10
0100          MD2=M-MD1*10
0101          IF(RFLAG) WRITE( 6,1060) RSYMB(14),S(I),S(J),MD1,MD2
0102          WRITE(11,1060) RSYMB(14),S(I),S(J),MD1,MD2
0103       45 CONTINUE
        C
        C   %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
        C
        C WATER BALANCE CONSTRAINTS
        C FRESH WATER DEMANDS
        C     SECTION B-4
        C
0104          DO 50 N=1,NTIME
0105          IF(RFLAG) WRITE( 6,1070) RSYMB(15),S(I),N
0106       50 WRITE(11,1070) RSYMB(15),S(I),N
0107     1070 FORMAT(1X,'G',2X,A3,A1,I1)
        C
        C   %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
        C
        C   TOTAL WATER DEMANDS
        C     SECTION B-5
        C
0108          DO 60 N=1,NTIME
```

```
0109          IF(RFLAG) WRITE( 6,1080) RSYMB(16),S(I),N
0110       60 WRITE(11,1080) RSYMB(16),S(I),N
0111     1080 FORMAT(1X,'G',2X,A3,A1,I1)
        C
        C   %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
        C
        C   DOWNSTREAM FLOW REQUIREMENTS
        C     SECTION B-6
        C
0112          DO 80 N=1,NTIME
0113          DO 80 KP=1,NPXX
0114          IF(RFLAG) WRITE( 6,1100)  RSYMB(17),S(I),N,KP
0115       80 WRITE(11,1100)  RSYMB(17),S(I),N,KP
0116     1100 FORMAT(1X,'L',2X,A3,A1,2I1)
0117      100 CONTINUE
        C
        C THIS COMPLETES THE ROW SECTION
        C
        C   %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
        C   %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
        C
        C COLUMN SECTION
        C     SECTION C
        C
        C   WRITE COLUMNS CONTROL CARD
        C
0118          IF(RFLAG) WRITE( 6,1115)
0119     1115 FORMAT(1X,'COLUMNS')
0120          WRITE(11,1120)
0121     1120 FORMAT('COLUMNS')
        C
        C   %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
        C
        C CONTINUOUS VARIABLE SECTION ** CYCLE BY PLANNING UNIT
        C     SECTION C-1
        C
        C   %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
        C
0122          DO 200 I=1,NPLAN
        C
        C   %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
        C
        C     QUANTITIES OF WATER REMOVED FROM STORAGE SYSTEMS AND PRODUCED BY
        C   DESALINIZATION PLANDS AND WATER TREATMENT PLANTS
        C     SECTION C-1-I
        C
        C
0123          NPXX=NPX(I)
        C
0124          DO 110 L=1,NP
0125          NPJ=NPROJ(L,I)
0126          IF(NPJ.EQ.0) GO TO 110
0127          DO 110 N=1,NTIME
0128          DO 110 M=1,NPJ
0129          MD1=M/10
0130          MD2=M-MD1*10
```

```
              C
              C    ADJUST OPERATION COSTS TO PRESENT VALUE
              C
0131                 COP=CO(L,I,M)/((1.0+R)**N)
              C
              C    WRITE OBJECTIVE FUNCTION-- OPERATING COSTS
              C
0132                 IF(RFLAG) WRITE(6,1130) CSYMB(L),S(I),N,MD1,MD2,OBNAME,COP
0133                 WRITE(11,1130) CSYMB(L),S(I),N,MD1,MD2,OBNAME,COP
0134           1130 FORMAT(4X,A3,A1,3I1,3X,A8,2X,F12.4)
              C
              C    TEST FOR NONEXISTING PROJECTS
              C    ENTER '-1' IN PROJECT INITIATION(I) CONSTRAINTS ROWS
              C    IF PROJECT ALREADY EXISTS, THEN THIS CONSTRAINT WILL BE REPLACED
              C    BY A BOUND ON THE COLUMN EQUAL TO THE CAPACITY OF THE PROJECT
              C
0135                 IF(RFLAG.AND..NOT.FXFLAG(L,I,M)) WRITE( 6,1135)CSYMB(L),S(I),N,
                   * MD1,MD2,RSYMB(L),S(I),N,MD1,MD2
0136                 IF(.NOT.FXFLAG(L,I,M)) WRITE(11,1135)CSYMB(L),S(I),N,MD1,MD2,
                   *RSYMB(L),S(I),N,MD1,MD2
0137           1135 FORMAT(4X,A3,A1,3I1,3X,A3,A1,3I1,8X,'-1.0000')
              C
              C    ENTER '1' IN THE FRESH WATER (DFW) CONSTRAINT ROW FOR
              C    FRESH WATER SOURCES.  IF NOT A FRESH WATER SOURCE THEN SKIP
              C    TO TOTAL DEMAND (DTW) CONSTRAINT ROW.
              C
0138                 IF (L.LT.3) GO TO 104
0139                 IF (RFLAG) WRITE(6,1140) CSYMB(L),S(I),N,MD1,MD2,RSYMB(15),S(I),N
0140                 WRITE(11,1140) CSYMB(L),S(I),N,MD1,MD2,RSYMB(15),S(I),N
              C
              C    IF PROJECT IS NOT A WTP ENTER '1' IN TOTAL WATER DEMAND (DTW) ROW
              C
0141                 IF(L.EQ.5) GO TO 110
0142            104 IF(RFLAG) WRITE( 6,1140) CSYMB(L),S(I),N,MD1,MD2,RSYMB(16),S(I),N
0143                 WRITE(11,1140) CSYMB(L),S(I),N,MD1,MD2,RSYMB(16),S(I),N
0144           1140 FORMAT(4X,A3,A1,3I1,3X,A3,A1,I1,11X,'1.0000')
              C
              C    IF PROJECT IS A DIVERSION OR RESERVOIR (L=1 OR 2), THEN ENTER ' 1'
              C    IN FLOW REQUIREMENTS CONTRAINT ROW (DFL).
              C
0145                 IF (L.EQ.3.OR.L.EQ.4) GO TO 106
              C
              C   SCAN INDEX CONTROL KPDFL TO DETERMINE WHICH FLOW REQUIREMENT IS TO
              C    BE APPLIED.  MATCH POINT(KP) TO PROJECT NUMBER(M) IN KPDFL MATRIX
              C    - KPDFL(I,KP,*) WHERE * IS 1,2--DIVERSIONS(L=1), 3,4--RESERVOIRS
              C    (L=2) AND 5,6--GW FIELDS(L=3). LOWER NUMBER OF EACH PAIR REPRESENTS
              C    FIRST PROJECT TO BE INCLUDED; SECOND NUMBER INDICATES LAST PROJECT
              C    TO BE INCLUDED.(INCLUSIVE RANGE).
              C
0146                 IF(L.EQ.2) GO TO 107
              C
              C    L MUST NOW BE 1
              C
0147                 DO 101 KP=1,NPXX
0148                 IF(M.LT.KPDFL(I,KP,1).OR. M.GT.KPDFL(I,KP,2)) GO TO 101
0149                 IF(RFLAG) WRITE(6,1142) CSYMB(L),S(I),N,MD1,MD2,RSYMB(17),S(I),N,
```

```
     1 KP
      WRITE(11,1142) CSYMB(L),S(I),N,MD1,MD2,RSYMB(17),S(I),N,KP
 1142 FORMAT(4X,A3,A1,3I1,3X,A3,A1,2I1,9X,' 1.0000')
  101 CONTINUE
      GO TO 110
C
C   L MUST NOW BE 2
C
  107 DO 102 KP=1,NPXX
      IF(M.LT.KPDFL(I,KP,3).OR. M.GT.KPDFL(I,KP,4)) GO TO 102
      IF(RFLAG) WRITE(6,1142) CSYMB(L),S(I),N,MD1,MD2,RSYMB(17),S(I),N,
     1 KP
      WRITE(11,1142) CSYMB(L),S(I),N,MD1,MD2,RSYMB(17),S(I),N,KP
  102 CONTINUE
      GO TO 110
C
C   IF PROJECT IS A GW FIELD, THEN ENTER INTERACTION COEFFICIENTS (F)
C   IN FLOW REQUIREMENTS (DFL) CONSTRAINT ROWS FOR PRESENT TIME
C   PERIOD AND ALL SUCCEDING TIME PERIODS.
C   IF PROJECT IS A DESALTING PLANT (L=4) GO TO END OF LOOP.
C
  106 IF (L.EQ.4) GO TO 110
C
      N2=0
      DO 109 N1=N,NTIME
      N2=N2+1
C
C   WRITE F VALUE. USE DUMMY VARIABLE TO STORE F VALUE.
C
      G=F(N2,I,M)
      DO 103 KP=1,NPXX
      IF(M.LT.KPDFL(I,KP,5).OR. M.GT.KPDFL(I,KP,6)) GO TO 103
      IF(RFLAG) WRITE(6,1144) CSYMB(L),S(I),N,MD1,MD2,RSYMB(17),S(I),N1,
     1 KP,G
      WRITE(11,1144) CSYMB(L),S(I),N,MD1,MD2,RSYMB(17),S(I),N1,KP,G
 1144 FORMAT(4X,A3,A1,3I1,3X,A3,A1,2I1,4X,F12.4)
  103 CONTINUE
  109 CONTINUE
  110 CONTINUE
C
C   %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
C
C   QUANTITIES OF RAW WATER IMPORTED
C     SECTION C-1-II
C
      DO 120 J=1,NPLAN
      IF(J.EQ.I) GO TO 120
      NPJ=NPIMP(I,J)
      IF(NPJ.EQ.0) GO TO 120
      DO 120 N=1,NTIME
      DO 120 M=1,NPJ
      MD1=M/10
      MD2=M-MD1*10
C
C   ADJUST OPERATING COSTS TO PRESENT VALUE
C
```

```
0181          COP=COIMP(I,J,M)/((1.0+R)**N)
        C
        C     WRITE OBJECTIVE FUNCTION -- OPERATING COSTS
        C
0182          IF(RFLAG) WRITE( 6,1150) CSYMB(6),S(I),S(J),N,MD1,MD2,OBNAME,COP
0183          WRITE(11,1150) CSYMB(6),S(I),S(J),N,MD1,MD2,OBNAME,COR
0184     1150 FORMAT(4X,A3,2A1,3I1,2X,A8,2X,F12.4)
        C
        C     TEST FOR NONEXISTING PROJECT
        C     ENTER '-1' IN PROJECT INITIATION(I) CONSTRAINT ROW FOR IMPORT
        C     PROJECT.
        C     EXISTING PROJECTS WILL BE BOUNDED REPLACING THIS CONSTRAINT.
        C
0185          IF(RFLAG.AND..NOT.IMPFIX(I,J,M)) WRITE(6,1155) CSYMB(6),S(I),S(J),
             * N,MD1,MD2,RSYMB(6),S(I),S(J),N,MD1,MD2
0186          IF(.NOT.IMPFIX(I,J,M)) WRITE(11,1155) CSYMB(6),S(I),S(J),N,MD1,
             * MD2,RSYMB(6),S(I),S(J),N,MD1,MD2
0187     1155 FORMAT(4X,A3,2A1,3I1,2X,A3,2A1,3I1,7X,'-1.0000')
        C
        C     ENTER '1' IN TOTAL WATER DEMAND ROW (DTW) AND '-1' IN SAME ROW OF
        C     PLANNING UNIT J TO INDICATE EXPORT.
        C
0188          IF(RFLAG) WRITE( 6,1160) CSYMB(6),S(I),S(J),N,MD1,MD2,RSYMB(16),S(
             *I),N,RSYMB(16),S(J),N
0189          WRITE(11,1160) CSYMB(6),S(I),S(J),N,MD1,MD2,RSYMB(16),S(I),N,
             1RSYMB(16),S(J),N
0190     1160 FORMAT(4X,A3,2A1,3I1,2X,A3,A1,I1,11X,'1.0000',3X,A3,A1,I1,
             * 10X,'-1.0000')
0191      120 CONTINUE
        C
        C %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
        C
        C     QUANTITIES OF TREATED WATER IMPORTED
        C
0192          DO 130 J=1,NPLAN
0193          IF(J.EQ.I) GO TO 130
0194          NPJ=NPIMQ(I,J)
0195          IF(NPJ.EQ.0) GO TO 130
0196          DO 130 N=1,NTIME
0197          DO 130 M=1,NPJ
0198          MD1=M/10
0199          MD2=M-MD1*10
        C
        C     ADJUST OPERATING COSTS TO PRESENT VALUE
        C
0200          COP=COIMQ(I,J,M)/((1.0+R)**N)
        C
        C     WRITE OBJECTIVE FUNCTION -- OPERATING COSTS
        C
0201          IF(RFLAG) WRITE( 6,1150) CSYMB(7),S(I),S(J),N,MD1,MD2,OBNAME,COP
0202          WRITE(11,1150) CSYMB(7),S(I),S(J),N,MD1,MD2,OBNAME,COR
        C
        C     TEST FOR NONEXISTING PROJECT
        C     ENTER '-1' IN PROJECT INITIATION(I) CONSTRAINT ROW FOR IMPORT
        C     PROJECT.
        C     EXISTING PROJECTS WILL BE BOUNDED REPLACING THIS CONSTRAINT.
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      C
0203        IF(RFLAG.AND..NOT.IMOFIX(I,J,M)) WRITE(6,1155) CSYMB(7),S(I),S(J),
           * N,MD1,MD2,RSYMB(7),S(I),S(J),N,MD1,MD2
0204        IF(.NOT.IMOFIX(I,J,M)) WRITE(11,1155) CSYMB(7),S(I),S(J),N,MD1,
           * MD2,RSYMB(7),S(I),S(J),N,MD1,MD2
      C
      C   ENTER '1' IN FRESH WATER DEMAND ROW (DFW) AND '-1' IN SAME ROW OF
      C   PLANNING UNIT J TO INDICATE EXPORT.
      C
0205        IF(RFLAG) WRITE( 6,1160) CSYMB(7),S(I),S(J),N,MD1,MD2,RSYMB(15),S(
           *I),N,RSYMB(15),S(J),N
0206        WRITE(11,1160) CSYMB(7),S(I),S(J),N,MD1,MD2,RSYMB(15),S(I),N,
           1RSYMB(15),S(J),N
      C
      C   ENTER '1' IN TOTAL WATER DEMAND ROW (DTW) AND '-1' IN SAME ROW OF
      C   PLANNING UNIT J TO INDICATE EXPORT.
      C
0207        IF(RFLAG) WRITE( 6,1160) CSYMB(7),S(I),S(J),N,MD1,MD2,RSYMB(16),S(
           *I),N,RSYMB(16),S(J),N
0208        WRITE(11,1160) CSYMB(7),S(I),S(J),N,MD1,MD2,RSYMB(16),S(I),N,
           1RSYMB(16),S(J),N
0209    130 CONTINUE
0210    200 CONTINUE
      C
      C   THIS ENDS THE CONTINUOUS VARIABLE SECTION.
      C
      C %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
      C %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
      C
      C   INTEGER VARIABLE SECTION -- CYCLE BY LAND UNIT
      C     SECTION C-1
      C     SECTION C-2-I
      C
      C   WRITE INTEGER MARKER CARD
      C
0211        IF(RFLAG) WRITE( 6,1310)
0212        WRITE(11,1310)
0213   1310 FORMAT(4X,'BEGIN',5X,'''MARKER''',17X,'''INTORG''')
      C
      C %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
      C
0214        DO 400 I=1,NPLAN
      C
      C %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
      C
      C   DECISIONS FOR BUILDING STORAGE FACILITIES, DESALINIZATION PLANTS,
      C   AND WATER TREATMENT PLANTS.
      C     SECTION C-2-II
      C
0215        DO 340 L=1,NP
0216        NPJ=NPROJ(L,I)
0217        IF(NPJ.EQ.0) GO TO 340
0218        DO 340 N=1,NTIME
0219        DO 340 M=1,NPJ
      C   [illegible]
      C   TEST FOR EXISTING PROJECTS. IF PROJECT EXISTS A DECISION VARIABLE
```

 (no page E12)

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            C   IS NOT NEEDED.
0220              IF(FXFLAG(L,I,M)) GO TO 340
0221              MD1=M/10
0222              MD2=M-MD1*10
            C
            C   CONVERT ANNUAL FIXED COSTS TO PRESENT VALUE ON AN
            C   ANNUAL BASIS AND SUM BY INCREMENTS EQUAL TO THE
            C   LENGTH OF A PLANNING PERIOD.
            C
            C   COMPUTE YEAR IN WHICH SUMMATION BEGINS (KBEGIN) AND ENDS (KEND).
            C
0223              KEND=NTIME*TIME
0224              KBEGIN=N*TIME-4
0225              LTIME=KEND-KBEGIN+1
0226              IF(NL(L,I,M).LT.LTIME) KEND=NL(L,I,M)+KBEGIN-1
            C
            C   RESET PRESENT VALUE MULTIPLIER
            C
0227              PV=0.
            C
            C   SUM PV FROM KBEGIN TO KEND
            C
0228              DO 330 K=KBEGIN, KEND
0229          330 PV=PV+(1./((1.+RPV)**K))
            C
            C   ADJUST ANNUAL FIXED COST OF PROJECT
            C
0230              CFIX=AFC(L,I,M)*PV
            C
0231              IF(CFIX.EQ.0.) GO TO 305
            C
            C   WRITE OBJECTIVE FUNCTION -- FIXED COSTS
            C
0232              IF(RFLAG) WRITE(6,1320) CSYMB(L+7),S(I),N,MD1,MD2,OBNAME,CFIX
0233              WRITE(11,1320) CSYMB(L+7),S(I),N,MD1,MD2,OBNAME,CFIX
0234         1320 FORMAT(4X,A3,A1,3I1,3X,A8,2X,F12.2)
            C
            C   WRITE PROJECT CAPACITIES FOR INITIALIZATION (I) CONSTRAINTS
            C
0235          305 DO 310 N1=N,NTIME
0236              IF(RFLAG) WRITE( 6,1330) CSYMB(L+7),S(I),N,MD1,MD2,RSYMB(L),
                 *S(I),N1,MD1,MD2,CAP(L,I,M)
0237          310 WRITE(11,1330) CSYMB(L+7),S(I),N,MD1,MD2,RSYMB(L),S(I),N1,MD1,MD2
                 *,CAP(L,I,M)
0238         1330 FORMAT(4X,A3,A1,3I1,3X,A3,A1,3I1,3X,F12.2)
            C
            C   WRITE PROJECT LIMITATION (L) CONSTRAINTS
            C
0239              IF(RFLAG) WRITE( 6,1340) CSYMB(L+7),S(I),N,MD1,MD2,RSYMB(L+7),S(I)
                 *,MD1,MD2
0240              WRITE(11,1340) CSYMB(L+7),S(I),N,MD1,MD2,RSYMB(L+7),S(I),MD1,MD2
0241         1340 FORMAT(4X,A3,A1,3I1,3X,A3,A1,2I1,10X,'1.0000')
0242          340 CONTINUE
            C
            C   %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
            C
```

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                C    DECISION FOR BUILDING TRANSPORT FACILITIES
                C      SECTION C-2-III
                C
0243                   DO 370 J=1,NPLAN
0244                   IF(J.EQ.I) GO TO 370
0245                   NPJ=NPIMP(I,J)
0246                   IF(NPJ.EQ.0) GO TO 370
0247                   DO 370 N=1,NTIME
0248                   DO 370 M=1,NPJ
0249                   IF(IMPFIX(I,J,M)) GO TO 370
0250                   MD1=M/10
0251                   MD2=M-MD1*10
                C
                C    CONVERT ANNUAL FIXED COSTS TO PRESENT VALUE ON AN
                C    ANNUAL BASIS AND SUM BY INCREMENTS EQUAL TO THE
                C    LENGTH OF A PLANNING PERIOD.
                C
0252                   KBEGIN=N*TIME-4.
0253                   KEND=NTIME*TIME
0254                   LTIME=KEND-KBEGIN+1
0255                   IF(NLIMP(I,J,M).LT.LTIME) KEND=NLIMP(I,J,M)+KBEGIN-1
                C
                C    RESET PRESENT VALUE MULTIPLIER
                C
0256                   PV=0.
                C
                C    SUM PV FROM KBEGIN TO KEND
                C
0257                   DO 350 K=KBEGIN, KEND
0258               350 PV=PV+(1./((1.+RPV)**K))
                C
                C    ADJUST ANNUAL FIXED COST OF PROJECT
                C
0259                   CFIX=AFCIMP(I,J,M)*PV
0260                   IF(CFIX.EQ.0.) GO TO 355
                C
                C    WRITE OBJECTIVE FUNCTION-- FIXED COSTS
                C
0261                   IF (RFLAG) WRITE(6,1350) CSYMB( 13),S(I),S(J),N,MD1,MD2,OBNAME,
                      1 CFIX
0262                   WRITE(11,1350) CSYMB( 13),S(I),S(J),N,MD1,MD2,OBNAME,CFIX
0263              1350 FORMAT(4X,A3,2A1,3I1,2X,A8,2X,F12.2)
                C
                C    WRITE PROJECT CAPACITIES FOR INITIALIZATION CONSTRAINTS
                C
0264               355 DO 360 N1=N,NTIME
0265                   IF (RFLAG) WRITE(6,1360) CSYMB( 13),S(I),S(J),N,MD1,MD2,
                      1 RSYMB(6),S(I),S(J),N1,MD1,MD2,CAPIMP(I,J,M)
0266               360 WRITE(11,1360) CSYMB( 13),S(I),S(J),N,MD1,MD2,RSYMB(6),S(I),S(J),
                      1 N1,MD1,MD2,CAPIMP(I,J,M)
0267              1360 FORMAT(4X,A3,2A1,3I1,2X,A3,2A1,3I1,2X,F12.2)
                C
                C    WRITE PROJECT LIMITATION (L) CONSTRAINTS
                C
0268                   IF (RFLAG) WRITE(6,1370) CSYMB( 13),S(I),S(J),N,MD1,MD2,
                      1 RSYMB( 13), S(I),S(J),MD1,MD2
```

```
      WRITE(11,1370) CSYMB( 13),S(I),S(J),N,MD1,MD2,RSYMB( 13),S(I),
     1 S(J),MD1,MD2
 1370 FORMAT(4X,A3,2A1,3I1,2X,A3,2A1,2I1,9X,'1.0000')
  370 CONTINUE
      DO 390 J=1,NPLAN
      IF(J.EQ.I) GO TO 390
      NPJ=NPIMQ(I,J)
      IF(NPJ.EQ.0) GO TO 390
      DO 390 N=1,NTIME
      DO 390 M=1,NPJ
      IF(IMQFIX(I,J,M)) GO TO 390
      MD1=M/10
      MD2=M-MD1*10
C
      KBEGIN=N*TIME-4.
      KEND=NTIME*TIME
      LTIME=KEND-KBEGIN+1
      IF(NLIMQ(I,J,M).LT.LTIME) KEND=NLIMQ(I,J,M)+KBEGIN-1
      PV=0.
C
      DO 375 K=KBEGIN, KEND
  375 PV=PV+(1./((1.+RPV)**K))
C
      CFIX=AFCIMQ(I,J,M)*PV
      IF(CFIX.EQ.0.) GO TO 380
C
C   WRITE OBJECTIVE FUNCTION-- FIXED COSTS
C
      IF (RFLAG) WRITE(6,1350) CSYMB( 14),S(I),S(J),N,MD1,MD2,OBNAME,
     1 CFIX
      WRITE(11,1350) CSYMB( 14),S(I),S(J),N,MD1,MD2,OBNAME,CFIX
C
C   WRITE PROJECT CAPACITIES FOR INITIALIZATION CONSTRAINTS
C
  380 DO 385 NI=N,NTIME
      IF (RFLAG) WRITE(6,1360) CSYMB( 14),S(I),S(J),N,MD1,MD2,
     1 RSYMB(7),S(I),S(J),NI,MD1,MD2,CAPIMQ(I,J,M)
  385 WRITE(11,1360) CSYMB( 14),S(I),S(J),N,MD1,MD2,RSYMB(7),S(I),S(J),
     1 NI,MD1,MD2,CAPIMQ(I,J,M)
C
C   WRITE PROJECT LIMITATION (L) CONSTRAINTS
C
      IF (RFLAG) WRITE(6,1370) CSYMB( 14),S(I),S(J),N,MD1,MD2,
     1 RSYMB( 14), S(I),S(J),MD1,MD2
      WRITE(11,1370) CSYMB( 14),S(I),S(J),N,MD1,MD2,RSYMB( 14),S(I),
     1 S(J),MD1,MD2
  390 CONTINUE
  400 CONTINUE
C
C  %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
C
C     SECTION C-2-IV
C
      IF(RFLAG) WRITE( 6,1400)
      WRITE(11,1400)
 1400 FORMAT(4X,'FINIS',5X,'''MARKER''',17X,'''INTEND''')
```

```
             C
             C   THIS ENDS THE INTEGER COLUMNS SECTION
             C
             C  %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
             C  %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
             C
             C   THIS SECTION SETS UP RIGHT HAND SIDES
             C     SECTION D
             C
             C   WRITE RHS MARKER CARD
             C     SECTION D-1
0302               IF(RFLAG) WRITE(6,1405)
0303          1405 FORMAT(' RHS')
0304               WRITE(11,1410)
0305          1410 FORMAT('RHS')
             C
             C  %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
             C
0306               DO 500 I=1,NPLAN
             C
             C  %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
             C
0307               NPXX=NPX(I)
             C
             C   PROJECT LIMITATION CONSTRAINTS FOR STORAGE,
             C   DESALINIZATION PLANTS AND TRANSPORT FACILITIES
             C     SECTION D-2
             C
0308               DO 410 L=1,NP
0309               NPJ=NPROJ(L,I)
0310               IF(NPJ.EQ.0) GO TO 410
0311               DO 410 M=1,NPJ
0312               IF(FXFLAG(L,I,M)) GO TO 410
0313               MD1=M/10
0314               MD2=M-MD1*10
0315               IF(RFLAG) WRITE(6,1420) RHNAME,RSYMB(L+7),S(I),MD1,MD2
0316               WRITE(11,1420) RHNAME,RSYMB(L+7),S(I),MD1,MD2
0317          1420 FORMAT(4X,A8,2X,A3,A1,2I1,10X,'1.0000')
0318           410 CONTINUE
             C
0319               DO 420 J=1,NPLAN
0320               IF(J.EQ.1) GO TO 420
0321               NPJ=NPIMP(I,J)
0322               IF(NPJ.EQ.0) GO TO 420
0323               DO 420 M=1,NPJ
0324               IF(IMPFIX(I,J,M))GO TO  420
0325               MD1=M/10
0326               MD2=M-MD1*10
0327               IF(RFLAG) WRITE(6,1430) RHNAME,RSYMB(13),S(I),S(J),MD1,MD2
0328               WRITE(11,1430) RHNAME,RSYMB(13),S(I),S(J),MD1,MD2
0329          1430 FORMAT(4X,A8,2X,A3,2A1,2I1,9X,'1.0000')
0330           420 CONTINUE
             C
0331               DO 425 J=1,NPLAN
0332               IF(J.EQ.1) GO TO 425
0333               NPJ=NPIMO(I,J)
```

```
      IF(NPJ.EQ.0) GO TO 425
      DO 425 M=1,NPJ
      IF(IMQFIX(I,J,M))GO TO  425
      MD1=M/10
      MD2=M-MD1*10
      IF(RFLAG) WRITE(6,1430) RHNAME,RSYMB(14),S(I),S(J),MD1,MD2
      WRITE(11,1430) RHNAME,RSYMB(14),S(I),S(J),MD1,MD2
  425 CONTINUE
C
C  %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
C
C    FRESH WATER DEMANDS
C      SECTION D-3
C
      DO 430 N=1,NTIME
      IF(RFLAG) WRITE(6,1440) RHNAME,RSYMB( 15),S(I),N,DFW(I,N)
      WRITE(11,1440) RHNAME,RSYMB( 15),S(I),N,DFW(I,N)
 1440 FORMAT(4X,A8,2X,A3,A1,I1,5X,F12.2)
  430 CONTINUE
C
C  %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
C
C      TOTAL WATER DEMANDS
C      SECTION D-4
C
      DO 440 N=1,NTIME
      IF(RFLAG) WRITE(6,1440) RHNAME,RSYMB( 16),S(I),N,TAD(I,N)
      WRITE(11,1440) RHNAME,RSYMB( 16),S(I),N,TAD(I,N)
  440 CONTINUE
C
C    DOWNSTREAM FLOW REQUIREMENTS
C
C      NOTE THAT KP IS USED TO INDEX MORE THAN ONE FLOW REQ.
C
      DO 450 KP=1,NPXX
      DFL=OFLOW(I,KP)-RFLOW(I,KP)
      DO 450 N=1,NTIME
      IF(RFLAG) WRITE(6,1445) RHNAME,RSYMB(17),S(I),N,KP,DFL
      WRITE(11,1445) RHNAME,RSYMB(17),S(I),N,KP,DFL
 1445 FORMAT(4X,A8,2X,A3,A1,2I1,4X,F12.2)
  450 CONTINUE
  500 CONTINUE
C
C    THIS ENDS THE RIGHT-HAND SIDE SECTION
C
C  %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
C  %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
C
C
C    SET UP BOUNDS
C      SECTION E
C
C    WRITE BOUNDS MARKER CARD
C      SECTION E-1
      IF(RFLAG) WRITE(6,1505)
 1505 FORMAT(' BOUNDS')
```

```
0361          WRITE(11,1510)
0362     1510 FORMAT('BOUNDS')
        C
        C %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
        C
        C  BOUNDS ON WITHDRAWALS FROM STORAGE AND DESALTING FACILITIES
        C    SECTION E-2
        C
0363          DO 550 I=1,NPLAN
0364          DO 550 L=1,NP
0365          NPJ=NPROJ(L,I)
0366          IF(NPJ.EQ.0) GO TO 550
0367          DO 550 N=1,NTIME
0368          DO 550 M=1,NPJ
0369          MD1=M/10
0370          MD2=M-MD1*10
0371          IF(RFLAG) WRITE(6,1515) BNAME,CSYMB(L),S(I),N,MD1,MD2,CAP(L,I,M)
0372          WRITE(11,1515) BNAME,CSYMB(L),S(I),N,MD1,MD2,CAP(L,I,M)
0373     1515  FORMAT(1X,'UP',1X,A8,2X,A3,A1,3I1,3X,F12.2)
0374      550 CONTINUE
        C
        C %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
        C
        C  BOUNDS ON TRANSPORT WATER
        C    SECTION E-3
        C
        C  RAW WATER
        C
0375          DO 575 I=1,NPLAN
0376          DO 575 J=1,NPLAN
0377          IF(I.EQ.J) GO TO 575
0378          NPJ=NPIMP(I,J)
0379          IF(NPJ.EQ.0) GO TO 575
0380          DO 575 N=1,NTIME
0381          DO 575 M=1,NPJ
0382          MD1=M/10
0383          MD2=M-MD1*10
0384          IF(RFLAG) WRITE(6,1517) BNAME,CSYMB(6),S(I),S(J),N,MD1,MD2,
             1 CAPIMP(I,J,M)
0385          WRITE(11,1517) BNAME,CSYMB(6),S(I),S(J),N,MD1,MD2,CAPIMP(I,J,M)
0386     1517 FORMAT(1X,'UP',1X,A8,2X,A3,2A1,3I1,2X,F12.2)
0387      575 CONTINUE
        C
        C  TREATED WATER
        C
0388          DO 580 I=1,NPLAN
0389          DO 580 J=1,NPLAN
0390          IF(I.EQ.J) GO TO 580
0391          NPJ=NPIMO(I,J)
0392          IF(NPJ.EQ.0) GO TO 580
0393          DO 580 N=1,NTIME
0394          DO 580 M=1,NPJ
0395          MD1=M/10
0396          MD2=M-MD1*10
0397          IF(RFLAG) WRITE(6,1517) BNAME,CSYMB(7),S(I),S(J),N,MD1,MD2,
             1 CAPIMO(I,J,M)
```

```
0398          WRITE(11,1517) BNAME,CSYMB(7),S(I),S(J),N,MD1,MD2,CAPIMQ(I,J,M)
0399      580 CONTINUE
        C
        C %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
        C
        C  BOUNDS ON DECISION VARIABLE FOR STORAGE
        C  AND DESALINIZATION FACILITIES
        C    SECTION E-4
        C
0400          DO 900 I=1,NPLAN
        C
0401          DO 820 L=1,NP
0402          NPJ=NPROJ(L,I)
0403          IF(NPJ.EQ.0) GO TO 820
0404          DO 820 N=1,NTIME
0405          DO 820 M=1,NPJ
        C
        C  CHECK FOR EXISTING PROJECTS
        C
0406          IF(FXFLAG(L,I,M)) GO TO 820
0407          MD1=M/10
0408          MD2=M-MD1*10
0409          IF(RFLAG) WRITE(6,1820) BNAME,CSYMB(L+7),S(I),N,MD1,MD2
0410          WRITE(11,1820) BNAME,CSYMB(L+7),S(I),N,MD1,MD2
0411     1820 FORMAT(1X,'UP',1X,A8,2X,A3,A1,3I1,9X,'1.0000')
0412      820 CONTINUE
        C
        C %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
        C
        C  BOUNDS ON  DECISION VARIABLE FOR TRANSPORT
        C  PROJECTS
        C    SECTION E-5
        C
        C  RAW WATER
        C
0413          DO 830 J=1,NPLAN
0414          IF(I.EQ.J) GO TO 830
0415          NPJ=NPIMP(I,J)
0416          IF(NPJ.EQ.0) GO TO 830
0417          DO 830 N=1,NTIME
0418          DO 830 M=1,NPJ
0419          IF(IMPFIX(I,J,M))GO TO  830
0420          MD1=M/10
0421          MD2=M-MD1*10
0422          IF(RFLAG) WRITE(6,1830) BNAME,CSYMB(13),S(I),S(J),N,MD1,MD2
0423          WRITE(11,1830) BNAME,CSYMB(13),S(I),S(J),N,MD1,MD2
0424     1830 FORMAT(1X,'UP',1X,A8,2X,A3,2A1,3I1,8X,'1.0000')
0425      830 CONTINUE
        C
        C  TREATED WATER
        C
0426          DO 840 J=1,NPLAN
0427          IF(I.EQ.J) GO TO 840
0428          NPJ=NPIMO(I,J)
0429          IF(NPJ.EQ.0) GO TO 840
0430          DO 840 N=1,NTIME
```

```
          DO 840 M=1,NPJ
          IF(IMOFIX(I,J,M))GO TO  840
          MD1=M/10
          MD2=M-MD1*10
          IF(RFLAG) WRITE(6,1830) BNAME,CSYMB(14),S(I),S(J),N,MD1,MD2
          WRITE(11,1830) BNAME,CSYMB(14),S(I),S(J),N,MD1,MD2
  840     CONTINUE
  900     CONTINUE
C
C   THIS ENDS THE BOUNDS SECTION
C
C  %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
C  %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
C    END OF DATA
C     SECTION F
C
          IF(RFLAG) WRITE(6,1905)
 1905     FORMAT(' ENDATA')
          WRITE(11,1900)
 1900     FORMAT('ENDATA')
          RETURN
          END
```

```
0001          SUBROUTINE DATA
        C
        C  * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
        C  *                                                                   *
        C  *                                                                   *
        C  *  SUBROUTINE READS DATA FOR MATRIX DATA                            *
        C  *                                                                   *
        C  *                          MATRIX DATA                              *
        C  *                                                                   *
        C  *    CARD ORDER                                                     *
        C  *       1. INIT-- PARAMETERS PNAME,OBNAME,RHNAME,BNAME,XWRITE        *
        C  *                 PARAMETERS NPLAN,NTIME,TIME,RPV,RAM               *
        C  *       2. SYMB-- PARAMETERS NRSYMB,NCSYMB, AND NP.                  *
        C  *       3. ROW AND COLUMN SYMBOLS AND DESCRIPTIONS.                  *
        C  *           A. RSYM-- ROW SYMBOLS.                                   *
        C  *           B. CSYM-- COLUMN SYMBOLS.                                *
        C  *       4. NWPP-- NUMBER OF PROJECTS IN EACH PLANNING UNIT.          *
        C  *       5. NRWT-- NUMBER OF RAW WATER TRANSPORT PROJECTS             *
        C  *       6. NTWT-- NUMBER OF TREATED WATER TRANSPORT PROJECTS.        *
        C  *       7. FCWP-- PARAMETERS FOR WATER PRODUCTION PROJECTS.          *
        C  *       8. FCWR-- PARAMETERS OF RAW WATER IMPORT PROJECTS.           *
        C  *       9. FCTW-- PARAMETERS FOR TREATED WATER IMPORT PROJECTS.      *
        C  *      10. DFWC-- FUTURE WATER DEMANDS.                              *
        C  *      11. SWGW-- SURFACE WATER-GROUND WATER INTERACTION COEFF.      *
        C  *      12. SWFL-- SURFACE WATER INFLOWS(UNREGULATED) AND RE-         *
        C  *           QUIRED OUTFLOWS.                                         *
        C  *                                                                   *
        C  * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
        C
0002          CONTINUE
        C
        C   DUMMY VARIABLES
        C   ARRAY INDEXES-- K,I,P
        C
0003          REAL*8 DUML(16)/13*'________',3*'        '/
0004          REAL*4 DUMFX1/'YES '/,DUMFX2/'NO  '/,DUMMY,TPS(8)/8*0./
0005          INTEGER FIX,NWELL(14)/14*0/
0006          LOGICAL RFLAG
0007          LOGICAL FXFLAG( 5, 8,10),IMPFIX( 8, 8,10),IMOFIX( 8, 8,10)
        C
        C   TEST WORDS FOR CARD ORDER CHECKS
        C
0008          REAL*4 TEST1/'NWPP'/,TEST2/'NRWT'/,TEST2A/'NTWT'/,TEST3/'FCWP'/,
             1 TEST4/'FCRW'/,TEST5/'FCTW'/,TEST6/'SWGW'/,TEST7/'SWFL'/,
             2 TEST8/'INIT'/,TEST9/'DFWC'/,TEST10/'SYMB'/,TEST11/'RSYM'/,
             3 TEST12/'CSYM'/,TEST13/'TITL'/,TEST14/'    '/
0009          REAL*4 NWPP,NRWT,NTWT,FCWP,FCRW,SWGW,SWFL,RSYM,CSYM,FCTW,
             1 INIT,DFWC,SYMB,TITLE,XWRITE
        C
        C
        C   ARRAYS FOR LABELLING PRINTOUT TABLES
        C
0010          REAL*4 RDESC(25,18),CDESC(25,18)
0011          REAL*4 TYPE(3,8)/'DIVE','RSIO','N - ','RESE','RVOI','R - ',
             1 'GW S','TORA','GE- ','DESA','LTIN','G - ','W T ','PLAN','T - ',
             2 'R WA','TER ','IMP-','T WA','TER ','IMP-','    ','    ','    '/
```

```
0012            LOGICAL*1 S(30)/'A','B','C','D','E','F','G','H','I','J','K'
               * 'M','N','O','P','Q','R','S','T','U','V','W','X','Y','Z','1
               * '3','4'/
0013            REAL*8 PNAME,OBNAME,RHNAME,BNAME
          C
          C
          C   LABELLED COMMON BLOCKS
          C    INITIALIZATION PARAMETERS
          C      ARRAY INDEXES-- NPROJ(K,I), NPIMP(I,J), NPIMQ(I,J)
          C
0014            COMMON/C1/ NPLAN,NTIME,NPROJ( 5, 8),NPIMP( 8, 8),NPIMQ( 8, 8),NP
          C
          C   ROW SYMBOLS AND COLUMN SYMBOLS-- MAX. 25
          C
0015            COMMON/C2/ NRSYMB,RSYMB(25),NCSYMB,CSYMB(25)
          C
          C   FIXED, OPERATING, ANNUAL FIXED COSTS FOR WATER PRODUCTION AND
          C      RAW AND TREATED WATER IMPORT PROJECTS
          C      ARRAY INDEXES--  CF(K,I,P),CO(K,I,P),CFIMP(I,J,P),CFIMQ(I,J,P)
          C                       COIMP(I,J,P),COIMQ(I,J,P)AFC(K,I,P),AFCIMP(I,J,P)
          C                       AFCIMQ(I,J,P)
          C
0016            COMMON/C3/ CF( 5, 8,10),CO( 5, 8,10),CFIMP( 8, 8,10),
               1 CFIMQ( 8, 8,10),COIMP( 8, 8,10),COIMQ( 8, 8,10),AFC( 5, 8,10),
               2 AFCIMP( 8, 8,10),AFCIMQ( 8, 8,10)
          C
          C   PERCENT WATER LOSSES DURING FESH WATER AND INTERMEDIATE QUALITY
          C      WATER USES.  ARRAY INDEXES-- PLFW(I,N), PLIW(I,N)
          C
0017            COMMON/C4/ PLFW( 8,10), PLIW( 8,10)
          C
          C   SURFACE WATER-GROUND WATER INTERACTION COEFFICIENTS AND RESULTING
          C      SURFACE WATER LOSSES. ARRAYS INDEXED-- PHI(N,I,P),F(N,I,P)
          C
0018            COMMON/C5/ PHI(10, 8,10), F(10, 8,10)
          C
          C   INITIALIZATION PARAMETERS
          C
0019            COMMON/C6/ TIME,R,RAM
          C
          C   MAXIMUM YIELD OR CAPACITY OF PROJECTS
          C      ARRAY INDEXES-- CAP(K,I,P),CAPIMP(I,J,P), CAPIMQ(I,J,P)
          C
0020            COMMON/C7/ CAP( 5, 8,10), CAPIMP( 8, 8,10),CAPIMQ( 8, 8,10)
          C
          C   WATER DEMANDS- FRESH WATER, INTERMEDIATE QUALITY WATER,ESTUARINE,
          C      AND TOTAL. ARRAY  INDEXES-- DFW(I,N), DIW(I,N),DEX(I,N), TAD(I,N)
          C   SW FLOWS TO GW WELL FIELDS AND REQUIRED FLOWS DOWNSTREAM
          C   OFLOW(I,K), RFLOW(I,K)
          C
0021            COMMON/C8/ DFW( 8,10),DIW( 8,10),DEX( 8,10),TAD( 8,10)
0022            COMMON/C8A/OFLOW( 8,10), RFLOW( 8,10)
          C
          C     ECONOMIC LIFE OF PROJECTS.  ARRAY INDEXES-- NL(K,I,P),
          C      NLIMP(I,J,P), NLIMQ(I,J,P)
          C
```

```
0023          COMMON/C9/ NL( 5, 8,10),NLIMP( 8, 8,10),NLIMQ( 8, 8,10)
        C
        C   PROJECT YIELDS IN MGD- MUST BE CONVERTED TO CAP,CAPIMP,AND CAPIMQ
        C      ARRAY INDEXES--  YLD(K,I,P), YLDIMP(I,J,P), YLDIMQ(I,J,P)
        C
0024          COMMON/C10/ YLD( 5, 8,10),YLDIMP( 8, 8,10), YLDIMQ( 8, 8,10)
        C
        C   DUMMY VARIABLES
        C
0025          COMMON/C11/ RFLAG
0026          COMMON/C12/ FXFLAG,IMPFIX,IMQFIX
        C
        C   INTEREST RATE FOR COMPUTING PRESENT VALUE
        C
0027          COMMON/C13/ RPV
        C
        C  NAMES OF DATA DECK,OBJ. FUNC.,RHS,AND BOUNDS
        C
0028          COMMON/C14/ PNAME,OBNAME,RHNAME,BNAME
        C
        C  INDEX CONTROL FOR FLOW REQUIREMENTS CONSTRAINTS. KPDFL(I,KP,*)
        C  WHERE * TAKES ON THE FOLLOWING VALUES. 1,2-DIVERSIONS(=2),
        C  3,4-RESERVOIRS(L=2); 5,6-GW FIELDS(L=3). FIRST AND SECOND VALUES OF
        C  EACH PAIR REPRESENT THE INCLUSIVE RANGE OF PROJECT NUMBERS OF EACH
        C  TYPE TO BE GROUP IN THE REQUIREMENT CONSTRAINT. THEREFORE THE
        C  PROJECT NUMBERS IN EACH TYPE MUST BE ASSIGNED IN ORDER.
        C
0029          COMMON/C15/KPDFL(8,5,6)
        C
        C  NUMBER OF REQUIRED FLOW POINTS IN EACH LAND UNIT. NPX(I)
        C
0030          COMMON/C16/ NPX(8)
        C
        C
        C   READ THE NUMBER OF PLANNING UNITS, THE NUMBER OF TIME PERIODS,
        C   LENGTH OF TIME PERIODS (YEARS), AND INTEREST RATE
        C
0031                    WRITE(6,1000)
0032     1000 FORMAT(11X,'PUERTO RICO WATER RESOURCES DEVELOPMENT PLANNING MODEL
             1'/11X,'MODEL DEFINITION AND CONTROL PROGRAM (MODCOP) - VERSION 3',
             * 3X, '5/11/73'//
             2/11X,'SUMMARY OF WATER RESOURCES PLANNING MODEL DATA'//)
0033          READ(5,1070) INIT
0034          IF(INIT.NE.TEST8) WRITE(6,1080) TEST8,INIT
0035          READ(5,1004) PNAME,OBNAME,RHNAME,BNAME,XWRITE
0036     1004 FORMAT(A8,A8,A8,A8,A4)
0037          IF(XWRITE.EQ.TEST14) RFLAG=.FALSE.
0038          READ(5,1005) NPLAN,NTIME,TIME,RPV,RAM
0039     1005 FORMAT(2I4,3F8.0)
        C
0040          DO 1 I=1,NPLAN
0041          DO 1 J=1,NPLAN
0042          NPIMP(I,J)=0
0043        1 NPIMQ(I,J)=0
        C
        C
```

```
C      CONVERT RPV TO R FOR TIME PERIOD - COMPOUND INTEREST
C
       R=(1.+RPV)**TIME-1.
C
       WRITE(6,1009) PNAME,OBNAME,RHNAME,BNAME
  1009 FORMAT(11X,'PROBLEM NAME                = ',A8/
     1        11X,'OBJECTIVE FUNCTION NAME     = ',A8/,
     2        11X,'RHS VECTOR NAME             = ',A8/,
     3        11X,'BOUNDS VECTOR NAME          = ',A8//)
                 WRITE(6,1010) NPLAN,NTIME,TIME,RPV,R,RAM
  1010 FORMAT(11X,'NUMBER OF PLANNING UNITS  =',I4/
     * 11X,'NUMBER OF TIME PERIODS    =',I4/
     * 11X,'LENGTH OF TIME PERIOD     =',F8.4,/
     * 11X,'ANNUAL INTEREST RATE      =',F8.4,/
     * 11X,'PERIOD INTEREST RATE      =',F8.4,/
     * 11X,'AMORTIZATION INTEREST RATE=',F8.4///)
C
C   READ NUMBER OF SYMBOLS AND SYMBOL CARDS
C      AND NUMBER OF TYPES OF WATER SUPPLY PROJECTS INCLUDING WATER
C      TREATMENT PLANTS
C
       READ(5,1070) SYMB
       IF(SYMB.NE.TEST10) WRITE(6,1080) TEST10,SYMB
       READ(5,1015) NRSYMB,NCSYMB,NP
  1015 FORMAT(3I4)
                 WRITE(6,1020)
  1020 FORMAT(11X,'LIST OF ROW SYMBOLS'/)
       DO 10 K=1,NRSYMB
       READ(5,1030) KK,RSYMB(K),(RDESC(K,J),J=1,18)
  1030 FORMAT(1X,I2,1X,19A4)
       IF(KK.NE.K) WRITE(6,1040)
  1040 FORMAT(' SYMBOL CARDS OUT OF ORDER')
    10           WRITE(6,1050) KK,RSYMB(K),(RDESC(K,J),J=1,18)
  1050 FORMAT(11X,'RSYMB(', I2,') = ',A4,2X,18A4)
       DO 20 K=1,NCSYMB
       READ(5,1030) KK,CSYMB(K),(CDESC(K,J),J=1,18)
       IF(KK.NE.K) WRITE(6,1040)
    20 IF(RFLAG) WRITE(6,1060) KK,CSYMB(K),(CDESC(K,J),J=1,18)
  1060 FORMAT(11X,'CSYMB(',I2,') = ', A4,2X,18A4)
C
C READ NUMBER OF PROJECTS IN EACH PLANNING UNIT
C
       READ(5,1070) NWPP
  1070 FORMAT(A4)
       IF(NWPP.NE.TEST1) WRITE(6,1080) TEST1,NWPP
  1080 FORMAT(' ERROR IN ORDER OF DATA CARDS! EXPECTED ',A4,
     *' BUT READ ',A4)
       DO 30 I=1,NPLAN
       READ(5,1095) KK,(NPROJ(K,KK),K=1,NP)
  1095 FORMAT(10I4)
       IF(KK.NE.I)  WRITE(6,1090) I,KK
  1090 FORMAT(' ERROR IN ORDER OF DATA CARDS! EXPECTED ',A4,
     *' BUT READ ',A4)
    30 CONTINUE
                 WRITE(6,1100) (S(JJ),JJ=1,NPLAN)
  1100 FORMAT('1'/11X,'SUMMARY OF NUMBER OF PROJECTS IN EACH PLANNING UNI
```

```
                 *T BY TYPE (NON-TRANSPORT)'// 4X,'TYPE',25X,'PLANNING UNIT ID'/11X,
                 1 30(3X,A1))
0079                    WRITE(6,1105) DUML
0080           1105 FORMAT('+',16A8//)
0081                 DO 40 K=1,NP
0082             40        WRITE( 6,1110) (TYPE(KK,K),KK=1,3),(NPROJ(K,I),I=1,NPLAN)
0083           1110 FORMAT(1X,2A4,A2,30I4)
               C
               C   READ IN NUMBER OF RAW WATER TRANSPORT PROJECTS
               C
0084                 READ(5,1070) NRWT
0085                 IF(NRWT.NE.TEST2) WRITE(6,1080) TEST2,NRWT
               C
0086                 DO 80 I=1,NPLAN
0087                 READ(5,1120) KK,J,NPJ
0088           1120 FORMAT(3I4)
0089                 IF(KK-I) 60,70,50
0090             50 WRITE( 6,1090) KK,I
0091             60 I=KK
               C
               C   CHECK FOR TERMINATING PROJECT COUNT FOR ITH PLANNING UNIT
               C
0092             70 IF(J.EQ.0) GO TO 80
0093                NPIMP(KK,J)=NPJ
0094                IF (I.EQ.NPLAN) I=NPLAN-1
0095             80 CONTINUE
0096                       WRITE(6,1130) (S(I),I=1,NPLAN)
0097           1130 FORMAT(1X//11X,'SUMMARY OF NUMBER OF RAW WATER IMPORT PROJECTS IN
                 1EACH PLANNING UNIT'//1X,'IMPORT TO', 23X,'FROM PLANNING UNIT'/
                 2 1X,'PLANNING'/3X,'UNIT'/11X,30(3X,A1))
0098                       WRITE(6,1135) DUML
0099           1135 FORMAT('+',16A8//)
0100                DO 90 I=1,NPLAN
0101             90        WRITE(6,1140) S(I),(NPIMP(I,J),J=1,NPLAN)
0102           1140 FORMAT(1X,'UNIT = ',A1,2X,30I4)
               C
               C   READ IN NUMBER OF TREATED WATER IMPORT PROJECTS
               C
0103                READ(5,1070) NTWT
0104                IF (NTWT.NE.TEST2A) WRITE(6,1080) TEST2A,NTWT
0105                DO 100 I=1,NPLAN
0106                READ(5,1120) KK,J,NPJ
0107                IF (KK-I) 94,96,92
0108             92 WRITE(6,1090) KK,I
0109             94 I=KK
               C
               C   CHECK FOR TERMINATING PROJECT COUNT FOR ITH PLANNING UNIT
               C
0110             96 IF(J.EQ.0) GO TO 100
0111                NPIMO(KK,J)=NPJ
0112                IF(I.EQ.NPLAN) I=NPLAN-1
0113            100 CONTINUE
0114                       WRITE(6,1131) (S(I),I=1,NPLAN)
0115           1131 FORMAT(1X, //11X,'SUMMARY OF NUMBER OF TREATED WATER IMPORT PROJEC
                 2TS IN EACH PLANNING UNIT'//1X,'IMPORT TO',23X,'FROM PLANNING UNIT'
                 3 /1X,'PLANNING'/3X,'UNIT'/11X,30(3X,A1))
```

```
                     WRITE(6,1135) DUML
          DO 110 I=1,NPLAN
      110            WRITE(6,1140) S(I),(NPIMQ(I,J),J=1,NPLAN)
C
C  *  COMPUTE THE NUMBER OF WATER PRODUCTION PROJECTS
          NPJ=0
          DO 120 I=1,NPLAN
          DO 120 K=1,NP
      120 NPJ=NPROJ(K,I)+NPJ
C
C    CHECK FOR ZERO PRODUCING PROJECTS
C
          IF (NPJ.EQ.0) GO TO 190
C  *  READ IN PARAMETERS FOR WATER PRODUCTION PROJECTS
C
          READ(5,1070) FCWP
          IF(FCWP.NE.TEST3) WRITE(6,1080) TEST3,FCWP
          DO 150 N=1,NPJ
          FIX=0
          READ(5,1150) I,K,L,NL(K,I,L),YLD(K,I,L),CF(K,I,L),CO(K,I,L),FIX
     1150 FORMAT(4I4,3F10.0,2X,I1)
          IF(FIX.EQ.1) FXFLAG(K,I,L)=.TRUE.
      150 CONTINUE
C
C    COMPUTE INTEREST RATE IN PERCENT
C
          RAMP=100.*RAM
                    WRITE(6,1160) TIME,RAMP
     1160 FORMAT('1',10X,'SUMMARY OF PROJECT PARAMETERS USED IN PR-WR PLANNI
         1NG MODEL'/22X,'WATER PRODUCTION PROJECT PARAMETERS'//25X,'PROJECT'
         2,14X,'YIELD OVER   FIXED      ANNUAL FIXED  OPERATING',8X,'TOTAL'/
         35X,'PLANNING  PROJECT    LIFE     SAFE YIELD  TIME PERIOD  COSTS
         4   COSTS AT        COSTS  EXIST-  SUPPLY'/6X,'UNIT',6X,'TYPE',
         * 6X,'(YRS)',5X,
         5 '(MGD)',6X,'(',F4.1,' YRS)',11X,F5.2,' PERCENT   PER MG',
         6 4X,'ING',4X,'(MG)')
                    WRITE(6,1165) DUML
     1165 FORMAT('+',16A8//)
          DO 165 I=1,NPLAN
          TPS(I)=0.
          DO 160 K=1,NP
          NPJ=NPROJ(K,I)
          IF(NPJ.EQ.0) GO TO 160
          DO 160 N=1,NPJ
C
C  *  COMPUTE ANNUAL COSTS
C
          IDUM=0
          CALL ACOST(I,K,N,IDUM)
C
C  *  CONVERT MGD YIELDS TO MG PER PLANNING PERIOD
C
          CAP(K,I,N)=365.*TIME*YLD(K,I,N)
          IF (K.EQ.5) GO TO 155
C    SUM CAPACITIES OF SUPPLY PROJECTS EXCLUDING TREATMENT PLANTS
          TPS(I)=CAP(K,I,N)+TPS(I)
```

```
0148        155 DUMMY=DUMFX2
0149            IF(FXFLAG(K,I,N)) DUMMY=DUMFX1
0150                      WRITE(6,1170) S(I),(TYPE(KK,K),KK=1,3),N,NL(K,I,N),
               1 YLD(K,I,N),CAP(K,I,N),CF(K,I,N),AFC(K,I,N),CO(K,I,N),DUMMY
0151       1170 FORMAT(7X,A1,5X,2A4,A3,I2,I4,5X,F6.2,2X,F10.0,2X,F11.0,
               1 3X,F11.0,1X,F9.2,4X,A4)
0152        160 CONTINUE
0153            WRITE(6,1175) TPS(I)
0154       1175 FORMAT(' ',94X,F12.0//)
0155        165 CONTINUE
          C
          C  *  COMPUTE THE NUMBER OF TRANSPORT PROJECTS
          C
0156        190 NPJ=0
0157            DO 200 I=1,NPLAN
0158            DO 200 J=1,NPLAN
0159            IF(J.EQ.I) GO TO 200
0160            NPJ=NPJ+NPIMP(I,J)
0161        200 CONTINUE
          C
          C   CHECK FOR ZERO TRANSPORT PROJECTS
          C
0162            IF (NPJ.EQ.0) GO TO 225
          C
          C   READ PARAMETERS OF RAW WATER IMPORT PROJECTS
          C
0163            READ(5,1070) FCRW
0164            IF(FCRW.NE.TEST4) WRITE(6,1080) TEST4,FCRW
          C
0165            DO 210 N=1,NPJ
0166            FIX=0
0167            READ(5,1150) I,J,L,NLIMP(I,J,L),YLDIMP(I,J,L),CFIMP(I+J,L),
               1 COIMP(I,J,L),FIX
0168        210 IF(FIX.EQ.1) IMPFIX(I,J,L)=.TRUE.
0169                      WRITE( 6,1180) TIME, RAMP,DUML
0170       1180 FORMAT('1',10X,'SUMMARY OF PROJECT PARAMETERS USED IN PR-WR PLANNI
               1NG MODEL'/22X,'RAW WATER IMPORT PROJECT PARAMETEPS'//24X,'PROJECT'
               2,14X,'CAPACITY       FIXED      ANNUAL FIXED  OPERATING'/5X,
               3 'PLANNING UNIT',8X,'LIFE     CAPACITY     TIME PERIOD  COSTS       C
               4OSTS AT     !  COSTS     EXISTING'/6X,'TO        FROM',8X,'(YRS)       (M
               5GD)        (',F4.1,1X,'YRS)',11X,F5.2,' PERCENT    PER MG'/'+',16A8//
               7 )
0171            DO 220 I=1,NPLAN
0172            DO 220 J=1,NPLAN
0173            IF(J.EQ.I) GO TO 220
0174            IF(I.EQ.0.OR.J.EQ.0) GO TO 220
0175            NPJ=NPIMP(I,J)
0176            IF(NPJ.EQ.0) GO TO 220
0177            DO 219 L=1,NPJ
          C
          C   COMPUTE ANNUAL COSTS-- NOTE THAT THE SECOND ARGUMENT OF ACOST MUST
          C      R-FER TO THE RAW WATER IMPORT PROJECT TYPE,E.G., K=6
          C
0178            CALL ACOST(I,6,L,J)
0179            CAPIMP(I,J,L)=365.*TIME*YLDIMP(I,J,L)
0180            DUMMY=DUMFX2
```

```
0214         250 CONTINUE
           C
           C  *  READ IN WATER DEMANDS
           C
0215         300 READ(5,1070) DFWC
0216             IF(DFWC.NE.TEST9) WRITE(6,1080) TEST9,DFWC
0217             DO 310 K=1,NPLAN
0218             DO 310 KK=1,NTIME
0219         310 READ(5,1200) I,N,DFW(I,N),PLFW(I,N),DIW(I,N),PLIW(I,N),DEX(I,N)
0220        1200 FORMAT(2I4,5F10.4)
           C
           C   WRITE TABLE OF WATER DEMANDS
           C
0221                       WRITE( 6,1210) DUML
0222        1210 FORMAT('1',11X,'SUMMARY OF WATER DEMANDS USED IN PR-WR PLANNING MO
                1DEL'//49X,'INTERMEDIATE'/4X,'PLANNING  TIME    FRESH WATER  FRESH
                2WATER    QUALITY     INTERMEDIATE            '/5X,'UNIT',5X,
                3 'PERIOD',5X,'DEMAND',4X,'USE FACTOR     DEMAND',7X,
                4 'USE FACTOR          '/25X,'(MGD)',21X,'(MGD)',22X,'     '
                5 '+',16A8//)
0223             DO 320 I=1,NPLAN
0224             DO 320 N=1,NTIME
0225         320           WRITE( 6,1220) S(I),N,DFW(I,N),PLFW(I,N),DIW(I,N),PLIW(I
                *,N)
0226        1220 FORMAT(6X,A1,7X,I4,5X,F8.2,6X,F6.4,6X,F8.2,8X,F6.4)
           C
           C   CONVERT WATER DEMANDS FROM MGD TO MG PER PLANNING PERIOD
           C
0227             DO 330 I=1,NPLAN
0228             DO 330 N=1,NTIME
0229             DFW(I,N)=365.*TIME*DFW(I,N)/(1.-PLFW(I,N))
0230             DIW(I,N)=365.*TIME*DIW(I,N)/(1.-PLIW(I,N))
0231         330 TAD(I,N)=DFW(I,N)+DIW(I,N)
           C
           C   WRITE TABLE OF DEMANDS PER PLANNING PERIOD
           C
0232                       WRITE( 6,1230) DUML
0233        1230 FORMAT('1',47X,'INTERMEDIATE'/4X,'PLANNING  TIME    FRESH WATER  F
                1RESH WATER    QUALITY     INTERMEDIATE              TOTAL ADJUSTED'
                * /5X,'UNIT',5X,
                2 'PERIOD',5X,'DEMAND',4X,'USE FACTOR     DEMAND',7X,
                3 'USE FACTOR          ',8X,'DEMAND'/25X,'(MG) ',21X,'(MG) ',
                4 22X,'      ',10X,'(MG)'/'+',16A8//)
0234             DO 340 I=1,NPLAN
0235             DO 340 N=1,NTIME
0236         340           WRITE( 6,1240) S(I),N,DFW(I,N),PLFW(I,N),DIW(I,N),PLIW(I
                *,N),         TAD(I,N)
0237        1240 FORMAT(6X,A1,7X,I4,2X,F11.2,6X,F6.4,3X,F11.2,8X,F6.4,14X,
                *4X,F12.2)
           C
           C  CHECK FOR ZERO GW FIELDS IN MODEL
           C
0238             NPJ=0
0239             DO 345 I=1,NPLAN
0240             NPJ=NPJ+NPROJ(3,I)
0241         345 CONTINUE
```

```
0181           IF(IMPFIX(I,J,L)) DUMMY=DUMFX1
0182                     WRITE( 6,1190) S(I),S(J),L,NLIMP(I,J,L),YLDIMP(I,J,L),
              1 CAPIMP(I,J,L),CFIMP(I,J,L),AFCIMP(I,J,L),COIMP(I,J,L),DUMMY
0183      1190 FORMAT(7X,A1,8X,A1,'-',I2,7X,I3,5X,F6.2,2X,F10.0,2X,F11.0,3X,
              1 F11.0,1X,F9.2,4X,A4)
0184       219 CONTINUE
0185       220 CONTINUE
          C
          C  *  COMPUTE THE NUMBER OF TRANSPORT PROJECTS
          C
0186       225 NPJ=0
0187           DO 230 I=1,NPLAN
0188           DC 230 J=1,NPLAN
0189           IF(J.EQ.I) GO TO 230
0190           NPJ=NPJ+NPIMQ(I,J)
0191       230 CONTINUE
          C
          C   CHECK FOR ZERO TRANSPORT PROJECTS
          C
0192           IF (NPJ.EQ.0) GO TO 300
          C
          C   READ PARAMETERS OF TREATED WATER IMPORT PROJECTS
          C
0193           READ(5,1070) FCTW
0194           IF(FCTW.NE.TEST5) WRITE(6,1080) TEST5,FCTW
0195           DO 240 N=1,NPJ
0196           FIX=0
0197           READ(5,1150) I,J,L,NLIMQ(I,J,L),YLDIMQ(I,J,L),CFIMQ(I,J,L),
              1 COIMQ(I,J,L),FIX
0198       240 IF(FIX.EQ.1) IMQFIX(I,J,L)=.TRUE.
0199                 WRITE( 6,1181) TIME, RAMP,DUML
0200      1181 FORMAT('1',10X,'SUMMARY OF PROJECT PARAMETERS USED IN PR-WR PLANNI
              ING MODEL'/22X,'TREATED WATER IMPORT PROJECT PARAMETERS'//24X,
              2 'PROJECT',14X,'CAPACITY     FIXED     ANNUAL FIXED  OPERATING'/
              3 5X,'PLANNING UNIT',8X,'LIFE    CAPACITY    TIME PERIOD  COSTS',
              5 6X,'COSTS AT       COSTS    EXISTING'/6X,'TO     FROM',8X,
              5 '(YRS)      (MGD)       (',F4.1,1X,'YRS)',11X,F5.2,' PERCENT   PER
              6MG'/'+',16A8//)
0201           DO 250 I=1,NPLAN
0202           DO 250 J=1,NPLAN
0203           IF(J.EQ.I) GO TO 250
0204           IF(I.EQ.0.OR.J.EQ.0) GO TO 250
0205           NPJ=NPIMQ(I,J)
0206           IF(NPJ.EQ.0) GO TO 250
0207           DO 249 L=1,NPJ
          C
          C   COMPUTE ANNUAL COSTS-- NOTE THAT THE SECOND ARGUMENT OF ACOST MUST
          C      REFER TO THE TREATED WATER IMPORT PROJECTS,E.G.,K=7
          C
0208           CALL ACOST(I,7,L,J)
0209           CAPIMQ(I,J,L)=365.*TIME*YLDIMQ(I,J,L)
0210           DUMMY=DUMFX2
0211           IF(IMQFIX(I,J,L)) DUMMY=DUMFX1
0212                 WRITE( 6,1190) S(I),S(J),L,NLIMQ(I,J,L),YLDIMQ(I,J,L),
              1 CAPIMQ(I,J,L),CFIMQ(I,J,L),AFCIMQ(I,J,L),COIMQ(I,J,L),DUMMY
0213       249 CONTINUE
```

```
0242             IF(NPJ.EQ.0) GO TO 399
           C
           C   READ IN SW-GW INTERACTION COEFFICIENTS
           C
0243             READ (5,1070) SWGW
0244             IF (SWGW.NE.TEST6) WRITE(6,1080) TEST6,SWGW
0245             DO 350 I=1,NPLAN
0246             NPJ=NPROJ(3,I)
           C
           C   CHECK FOR ZERO PROJECTS
           C
0247             IF (NPJ.EQ.0) GO TO 350
0248             DO 355 L=1,NPJ
0249             READ (5,1400) II,LL,(PHI(N,I,L),N=1,NTIME)
0250        1400 FORMAT(2I4,9F8.0,(10F8.0))
0251             IF (II.NE.I) WRITE(6,1090) I,II
0252             IF (LL.NE.L) WRITE(6,1090) L,LL
0253         355 CONTINUE
0254         350 CONTINUE
0255                         WRITE(6,1410) DUML
0256        1410 FORMAT('1',10X,'SUMMARY OF SW-GW INTERACTION COEFFICIENTS'//
                1 1X,'PLANNING',1X,'TIME',15X,'WELL FIELD NUMBER'/3X,'UNIT',2X,
                2 'PERIOD'/'+',16A8//)
0257             DC 375 I=1,NPLAN
0258             NPJ=NPROJ(3,I)
           C
           C   CHECK FOR ZERO PROJECTS
           C
0259             IF (NPJ.EQ.0) GO TO 375
0260             DO 360 KKK=1,NPJ
0261         360 NWELL(KKK)=KKK
0262                         WRITE(6,1420) I,(NWELL(NX),NX=1,NPJ)
0263        1420 FORMAT(/,1X,I4,10X,14(2X,I4,2X))
0264             DO 370 N=1,NTIME
0265         370             WRITE(6,1430) N,(PHI(N,I,L),L=1,NPJ)
0266        1430 FORMAT(9X,I4,2X,14(F8.5))
0267         375 CONTINUE
           C
           C   COMPUTE GW PUMPING EFFECTS, ETC.
           C
0268             CALL GWCOMP
           C
0269                         WRITE(6,1440) DUML
0270        1440 FORMAT('1',10X,'SUMMARY OF SW WITHDRAWALS DUE TO GW PUMPING'//
                2 1X,'PLANNING',1X,'TIME',15X,'WELL FIELD NUMBER',/3X,'UNIT',2X,
                3 'PERIOD'/'+',16A8//)
0271             DO 395 I=1,NPLAN
0272             NPJ=NPROJ(3,I)
           C
           C   CHECK FOR ZERO PROJECTS
           C
0273             IF (NPJ.EQ.0) GO TO 395
0274             DO 380 KKK=1,NPJ
0275         380 NWELL(KKK)=KKK
0276                         WRITE(6,1420) I,(NWELL(NX),NX=1,NPJ)
0277             DO 390 N=1,NTIME
```

```
  390           WRITE(6,1450) N,(F(N,I,L),L=1,NPJ)
 1450 FORMAT(9X,I4,2X,14(F8.5))
  395 CONTINUE
C
C   READ IN UPLAND DISCHARGES TO VALLEYS AND REQUIRED OUTFLOWS
C
  399 READ (5,1070) SWFL
      IF (SWFL.NE.TEST7) WRITE(6,1080) TEST7,SWFL
      DO 400 I=1,NPLAN
  400 READ (5,1500) II,NPX(II)
 1500 FORMAT(2I4)
                   WRITE(6,1520) DUML
      DO 420 I=1,NPLAN
      NPP=NPX(I)
C
C   CHECK FOR ZERO PROJECT POINTS
C
      IF (NPP.EO.0) GO TO 420
      DO 410 J=1,NPP
      READ (5,1510) QFLOW(I,J),RFLOW(I,J)
 1510 FORMAT(8X,2F8.0)
      WRITE(6,1525) I,J,QFLOW(I,J),RFLOW(I,J)
 1525 FORMAT(3X,I4,4X,I4,3X,F8.2,10X,F8.2)
C
C  READ IN LINKS BETWEEN RESERVOIRS,DIVERSIONS,GW FIELDS
C
      READ(5,1515) (KPDFL(I,J,LIM),LIM=1,6)
 1515 FORMAT(8X,6I4)
      WRITE(6,1526) I,J,(KPDFL(I,J,LIM),LIM=1,6)
 1526 FORMAT(3X,I4,4X,I4,4X,3(I4,2X,I4,4X)//)
C
C   CONVERT MGD TO MG PER PLANNING PERIOD
C
      QFLOW(I,J)=365.*QFLOW(I,J)*TIME
  410 RFLOW(I,J)=365.*RFLOW(I,J)*TIME
  420 CONTINUE
                   WRITE(6,1520) DUML
 1520 FORMAT('1',10X,'SUMMARY OF NATURAL INFLOWS AND REQUIRED OUTFLOWS'
     2 // 1X,'PLANNING',2X,'POINT',3X,'NATURAL',10X,'REQUIRED'/
     3 3X,'UNIT',4X,'NUMBER',3X,'FLOWS',12X,'FLOWS'/,'+',16A8//)
      DO 430 I=1,NPLAN
      NNP=NPX(I)
C
C   CHECK FOR ZERO PROJECT POINTS
C
      IF (NNP.EO.0) GO TO  430
      DO 440 J=1,NNP
  440              WRITE(6,1530) I,J,QFLOW(I,J),RFLOW(I,J)
 1530 FORMAT(3X,I4,4X,I4,3X,F8.0,10X,F8.0)
  430 CONTINUE
C
C   READ TITLES FOR PROJECT (OPTIONAL)
C
      READ(5,1070,END=2000) TITLE
      WRITE(6,1610) DUML
 1610 FORMAT('1',10X,'KEY TO NAMES OF PROJECTS'/'+',16A8//)
```

```
      IF (TITLE.NE.TEST13) WRITE(6,1080) TEST13,TITLE
  500 READ(5,1600,END=2000) I,K,M,(RDESC(1,KK),KK=1,15)
 1600 FORMAT(3I4,8X,15A4)
      WRITE(6,1620) S(I),(TYPE(KK,K),KK=1,3),M,(RDESC(1,KK),KK=1,15)
 1620 FORMAT(1X,A1,2X,3A4,I4,5X,15A4)
      GO TO 500
 2000 RETURN
      END
```

```
      SUBROUTINE ACOST(I,K,M,J)
      COMMON/C3/ CF( 5, 8,10),CO( 5, 8,10),CFIMP( 8, 8,10),
     1 CFIMQ( 8, 8,10),COIMP( 8, 8,10),COIMQ( 8, 8,10),AFC( 5, 8,10),
     2 AFCIMP( 8, 8,10),AFCIMQ( 8, 8,10)
      COMMON/C6/ TIME,R,RAM
      COMMON/C9/ NL( 5, 8,10),NLIMP( 8, 8,10),NLIMQ( 8, 8,10)
C
C     COMPUTE ANNUAL COSTS
C
      IF(K.EQ.6) GO TO 6
      IF(K.EQ.7) GO TO 7
      N=NL(K,I,M)
      GO TO 10
    6 N=NLIMP(I,J,M)
      GO TO 10
    7 N=NLIMQ(I,J,M)
   10 IF(N.EQ.0) GO TO 12
      CRF=(RAM*(1.+RAM)**N)/((1.+RAM)**N-1.)
      GO TO 14
   12 CRF=0.
   14 IF(K.EQ.6) GO TO 16
      IF(K.EQ.7) GO TO 17
      AFC(K,I,M)=CRF*CF(K,I,M)
      GO TO 20
   16 AFCIMP(I,J,M)=CRF*CFIMP(I,J,M)
      GO TO 20
   17 AFCIMQ(I,J,M)=CRF*CFIMQ(I,J,M)
   20 RETURN
      END
```

```
0001         SUBROUTINE GWCOMP
0002         COMMON/C1/ NPLAN,NTIME,NPROJ( 5, 8),NPIMP( 8, 8),NPIMQ( 8, 8)
0003         COMMON/C5/ PHI(10, 8,10), F(10, 8,10)
      C
      C      COMPUTE SW-GW INTERACTIONS
      C
0004         DO 20 I=1,NPLAN
0005         NPJ=NPROJ(3,I)
      C
      C    CHECK FOR ZERO PROJECTS
      C
0006         IF (NPJ.EQ.0) GO TO 20
0007         DO 10 L=1,NPJ
0008         F(1,I,L)=PHI(1,I,L)
0009         DO 10 N=2,NTIME
0010         M=N-1
0011      10 F(N,I,L)=PHI(N,I,L)-PHI(M,I,L)
0012      20 CONTINUE
0013         RETURN
0014         END
```

```
0001      BLOCK DATA
0002      COMMON/C1/ NPLAN,NTIME,NPROJ,NPIMP,NPIMQ,NP
0003      COMMON/C2/ NRSYMB,RSYMB,NCSYMB,CSYMB
0004      COMMON/C3/ CF,CO,CFIMP,CFIMQ,COIMP,COIMQ,AFC,AFCIMP,AFCIMQ
0005      COMMON/C4/ PLFW,PLIW
0006      COMMON/C5/ PHI,F
0007      COMMON/C7/ CAP,CAPIMP,CAPIMQ
0008      COMMON/C8/ DFW,DIW,DEX,TAD
0009      COMMON/C8A/ QFLOW,RFLOW
0010      COMMON/C9/ NL,NLIMP,NLIMQ
0011      COMMON/C10/ YLD,YLDIMP,YLDIMQ
0012      COMMON/C11/ RFLAG
0013      COMMON/C12/ FXFLAG,IMPFIX,IMQFIX
0014      COMMON/C14/ PNAME,OBNAME,RHNAME,BNAME
0015      COMMON/C15/KPDFL
0016      COMMON/C16/ NPX
     C
     C
0017      INTEGER NPROJ(5,8)/40*0/,NPIMP(8,8)/64*0/,NPIMQ(8,8)/64*0/,NP/5/
0018      REAL*8 PNAME/'PR1     '/,OBNAME/'MINCOST '/,RHNAME/'RS      '/,
         1 BNAME/'BND     '/
0019      REAL RSYMB(25)/25*'    '/,CSYMB(25)/25*'    '/
0020      REAL CF( 5, 8,10)/400*0./, CO( 5, 8,10)/400*0./,
         1 CFIMP( 8, 8,10)/640*0./, CFIMQ( 8, 8,10)/640*0./,
         2 COIMP( 8, 8,10)/640*0./, COIMQ( 8, 8,10)/640*0./,
         3 AFC( 5, 8,10)/400*0./, AFCIMP( 8, 8,10)/640*0./,
         4 AFCIMQ( 8, 8,10)/640*0./
0021      REAL PLFW( 8,10)/80*0./, PLIW( 8,10)/80*0./
0022      REAL PHI(10, 8,10)/800*0./, F(10, 8,10)/800*0./
0023      REAL CAP( 5, 8,10)/400*0./,CAPIMP( 8, 8,10)/640*0./,
         1 CAPIMQ( 8, 8,10)/640*0./
0024      REAL DFW( 8,10)/80*0./,DIW( 8,10)/80*0./,DEX( 8,10)/80*0./,
         1 TAD( 8,10)/80*0./
0025      REAL QFLOW( 8,10)/80*0./, RFLOW( 8,10)/80*0./
0026      INTEGER NL( 5,8,10)/400*0/, NLIMP( 8, 8,10)/640*0/,
         1 NLIMQ( 8, 8,10)/640*0/
0027      INTEGER KPDFL(8,5,6)/240*0/
0028      INTEGER NPX(8)/8*0/
0029      REAL YLD( 5, 8,10)/400*0./,YLDIMP( 8, 8,10)/640*0./,
         1 YLDIMQ( 8, 8,10)/640*0./
0030      LOGICAL RFLAG/.TRUE./
0031      LOGICAL FXFLAG(5,8,10)/400*.FALSE./,IMPFIX(8,8,10)/640*.FALSE./,
         1 IMQFIX( 8 8,10)/640*.FALSE./
0032      END
```

F88-LEVEL LINKAGE EDITOR OPTIONS SPECIFIED MAP,LET,LIST,DC
DEFAULT OPTION(S) USED - SIZE=(100352,14336)

MODULE MAP

CONTROL SECTION			ENTRY							
NAME	ORIGIN	LENGTH	NAME	LOCATION	NAME	LOCATION	NAME	LOCATION	NAME	LOCATION
MAIN	00	130								
PR	130	5084								
DATA	5188	4FCE								
ACOST	A188	45C								
GWCOMP	A5E8	25E								
C1	A848	2AC								
C14	AAF8	20								
C2	AB18	D0								
C3	ABE8	4EC0								
C4	FAA8	280								
C5	FD28	1900								
C7	11628	1A40								
C8	13068	500								
C8A	13568	280								
C9	137E8	1A40								
C15	15228	3C0								
C16	155E8	20								
C10	15608	1A40								
C11	17048	4								
C12	17050	1E00								
IHCFEXIT*	18E50	1C	EXIT	18E50						
IHCFRXPI*	18E70	141	FRXPI#	18E70						
IHCFRXPR*	18FB8	183	FRXPR#	18FB8						
IHCECOMH*	19140	F41	IBCOM#	19140	FDIOCS#	191FC	INTSWTCH	1A066		
IHCCOMH2*	1A088	65D	SEQDASD	1A400						
IHCFCVTH*	1A6E8	119D	ADCON#	1A6E8	FCVAOUTP	1A792	FCVLOUTP	1A822	FCVZOUTP	1A972
			FCVIOUTP	1AD20	FCVEOUTP	1B222	FCVCOUTP	1B43C	INT6SWCH	1B723
IHCSLOG *	1B888	1B6	ALOG10	1B888	ALOG	1B8A0				
IHCEFNTH*	1BA40	512	ARITH#	1BA40	ADJSWTCH	1BDAC				
IHCSEXP *	1BF58	192	EXP	1BF58						
IHCEFIOS*	1C0F0	1378	FIOCS#	1C0F0	FIOCSBEP	1C0F6				
IHCUOPT *	1D468	350								
IHCERRM *	1D7B8	3BC	ERRMON	1D7B8	IHCERRE	1D7D0				

NAME	ORIGIN	LENGTH	NAME	LOCATION	NAME	LOCATION	NAME	LOCATION	NAME	LOCATION
IHCUATBL*	1DD78	148								
IHCETRCH*	1DEC0	28E	IHCTRCH	1DEC0	ERRTRA	1DEC8				
C6	1E150	C								
C13	1E160	4								

ENTRY ADDRESS 00
TOTAL LENGTH 1E168

****VER3 DOES NOT EXIST BUT HAS BEEN ADDED TO DATA SET