SUPPLEMENT TO THE NEW MEXICO THREE-DIMENSIONAL MODEL

(Supplement to Open-File Report 80-421)

By Glenn A. Hearne

U.S. GEOLOGICAL SURVEY

Open-File Report 82-857

U.S. DEPARTMENT OF THE INTERIOR
MARCH 3, 1849

Albuquerque, New Mexico

1982

UNITED STATES DEPARTMENT OF THE INTERIOR

JAMES G. WATT, Secretary

GEOLOGICAL SURVEY

Dallas L. Peck, Director

For additional information
write to:

District Chief
U.S. Geological Survey
Water Resources Division
505 Marquette NW, Room 720
Albuquerque, New Mexico 87102

For sale by:

Open-File Services Section
Branch of Distribution
U.S. Geological Survey, MS 306
Box 25425, Denver Federal Center
Denver, Colorado 80225
(303) 234-5888

CONTENTS

Page

Abstract 1

Introduction 1

Caution to users and disclaimer 2

Program changes 2

  Head-dependent flow boundaries 2

  Specified-flow boundaries 3

  Conversion to CRAY-1 4

User's guide 5

  Equations of flow 5

  Boundary conditions 7

    Specified head 8

    Specified flow 8

    Head-dependent flow 9

  Compiling a program to execute on CRAY-1 11

    CDC control block: Records 1 through 24 13

    UPDATE control block: Records 25 through 41 14

    CRAY-1 control block: Records 42 through 56 22

  Program input requirements 23

    Data input block 1: Program execution 23

    Data input block 2: NAMELIST $CONTROL 25

    Data input block 3: I/O control record 29

    Data input block 4: NAMELIST $INLIST 29

    Data input block 5: HEADING 38

CONTENTS - Concluded

Page

User's guide - Concluded:

Program input requirements - Concluded:

Data input block 6: SYMBOLS 39

Data input block 7: 3D INPUT 40

Data input block 8: 2D INPUT 44

Data input block 9: OUTPUT CUBES 46

Data input block 10: ENDOFCUBES 49

Data input block 11: NAMELIST $NEWPP 50

Data input block 12: NAMELIST $NEWELL 51

Data input block 13: NAMELIST $NEWRIV 52

Sample simulation 54

Steady-state simulation 54

Transient simulation 75

References 90

ILLUSTRATIONS

Page

Figure 1. Graph of function describing ground-water flow at a head-dependent flow boundary 9

2. Coding form for input of symbol-value pairs (block 6) 39

3. Coding form for input of 3D variables (block 7) showing fields 1-26 and the default locations 42

4. Coding form for input of 2D variables (block 8) showing fields 1-8 and permissible keywords 45

5. Coding form for specifying output (block 9) showing fields 1-13 and permissible keywords 46

TABLES

Table 1. Job stream for compiling a program to execute on CRAY-1 12

2. Job stream for executing a program on CRAY-1 with the data input on a CDC permanent file 24

3. Job stream for executing a program on CRAY-1 through remote job entry (RJE) of a disk file on the HARRIS minicomputer . 26

4. Number of 3D array variables per node (NVPN) 31

5. Default values for the LC... variables 38

6. Acceptable combinations of keywords, numbers, and symbols for OUTPUT CUBES 47

7. Job stream used for steady-state simulation with multiple "rivers" defined for some nodes 55

8. Job stream used for transient simulation with "rivers" and "wells" changing with time 76

SUPPLEMENT TO THE NEW MEXICO THREE-DIMENSIONAL MODEL
(Supplement to Open-File Report 80-421)

By Glenn A. Hearne

ABSTRACT

The computer program documented in Open-File Report 80-421 has continued to evolve in response to needs. Changes as of January 1981 included the following: (1) Treatment of head-dependent boundaries and specified-flow boundaries; and (2) code which executes on the CRAY-1 computer. This report provides instructions for compiling and executing the computer program on the CRAY-1 at Kirtland Air Force Base.

INTRODUCTION

Within the U.S. Geological Survey, computer programs for simulating geohydrologic systems are frequently changed by the hydrologist/modeler to accommodate the characteristics of the particular ground-water flow system being modeled and the computer system available.

This supplement describes improvements to the computer code since the original documentation published as Open-File Report 80-421 (Posson and others, 1980). A guide is provided for executing the program on the CRAY-1 at Kirtland Air Force Base. The changes completed by January 1981 were motivated by intended use of the program on the CRAY-1 at Kirtland Air Force Base by the Southwest Alluvial Basin (east) Regional Aquifer System Analysis (Wilkins, Scott, and Kaehler, 1980).

The report consists of a brief description of the changes, a current user's guide, and a sample simulation. The user's guide is identical to the one in Open-File Report 80-421 (Posson and others, 1980) except for modifications related to changes in the computer program. Entire sections of the earlier report are reproduced here with no substantial change to provide a complete user's guide in one reference.

The program assumes the units of time to be seconds except where noted in the documentation. Units of length, area, and volume may be in any consistent units (meters or feet); in this report units of length are assumed to be in feet.

CAUTION TO USERS AND DISCLAIMER

The user of this program is cautioned to verify that the program is in fact functioning as intended for the specific data being used. Not all options have been exhaustively tested; therefore, the program could contain undiscovered errors and is subject to revision as errors are encountered. The user is advised to contact the author for current information about the program.

The data processing techniques used in the program were originally developed on computers manufactured by Control Data Corporation and have now been modified to execute on computers manufactured by Cray Research, Inc.[1]

PROGRAM CHANGES

Head-dependent flow boundaries

A head-dependent flow boundary can be used to represent streams, canals, drains, or evapotranspiration. The nodes selected to represent streams are grouped into reaches such that the interior nodes of each reach are isolated from other reaches. The user defines each reach and the nodes within the reach in the order in which they are to be processed. For each pumping period, the flow available in the first node of each reach is the total of the flow specified by the user and the flow routed to this reach from other reaches. As each node is processed, the flow available in the stream is modified by gains from or losses to ground water. At the end of each reach the flow available in the stream may be routed to the first node of another reach.

The treatment of head-dependent flow boundaries has been changed to (1) allow representation of more than one boundary in each cell, (2) simplify the input required to represent changes to the boundary condition during a simulation, (3) provide a method for dimensioning the necessary arrays, and (4) improve stability and convergence.

In some instances, the user may wish to represent a stream, an irrigation drain, and evapotranspiration from ground water as head-dependent flow boundaries in the same cell. The program now algebraically accumulates the flow rates as each head-dependent boundary node is processed.

Changes in the properties defining head-dependent flow boundaries may be specified for each pumping period. The current values are printed out at the start of each pumping period.

---

[1] The use of manufacturers names in this report is for indentification purposes only and does not constitute endorsement by the U.S. Geological Survey.

The arrays required for the head-dependent flow boundaries must be dimensioned when the program is compiled. The method for doing this is given on page 21 in the user's guide.

The explicit calculation of flow at a head-dependent flow boundary (Posson and others, 1980, p. 15) causes slow convergence in some instances and instability in others. To alleviate this condition, the calculation has been made iteratively implicit by using the head calculated at the last iteration rather than the head calculated at the last time step.

Even with the flow rates being iteratively implicit, there may be difficulty with the model either (1) converging to a solution in which the error in the mass balance is large, (2) converging very slowly, or (3) becoming unstable and failing to converge. In many instances, these difficulties can be overcome by adjusting one or more of the following: closure criteria, size of the time step, rate of logarithmic increase in time step, or damping factor.

The most unstable situation appears to be simulation of a steady-state condition in which many nodes are head-dependent flow boundaries. Here, stability has been achieved by simulating many short time steps rather than one long one. This requires that (1) storage (or specific yield for water table) be set to some positive value; (2) initial head be set equal to the boundary head; (3) a long period of time be simulated by several pumping periods; (4) in each pumping period the time step remain constant and be small enough to prevent oscillation; and (5) closure criteria be small enough so that most time steps require more than one iteration. In some cases, stability may be improved by setting the damping factor to a value less than 1.0. Approach to steady-state condition may be seen in the change in storage reported in the mass balance; when the rate of change in storage becomes negligible, the BAKOUT file can be used as a BAKIN file for a simulation that sets storage to zero and simulates a steady-state condition in one time step.

Specified-flow boundaries

The treatment of specified-flow boundaries has been changed to simplify the input required to represent changes to the boundary condition during a simulation. Discharge multiplying factors may be redefined each pumping period. At the start of each new pumping period, the current values of the multiplying factors are used to compute the pumping rate for each well; these pumping rates are accumulated for each node.

Conversion to CRAY-1

For ground-water modeling, the New Mexico District office of the U.S. Geological Survey, Water Resources Division, uses the computer facility operated by the Air Force Weapons Laboratory, Kirtland Air Force Base. Shortly after the original documentation (Posson and others, 1980) was published, Kirtland Air Force Base modified the hardware configuration at the site. The Control Data Corporation Cyber 170 model 176 (for which the earlier computer program was designed) was replaced by a CRAY-1 computer. Modification of the computer program to execute on the CRAY-1 was completed by Kentron under contract from the U.S. Geological Survey (Kentron, 1980).

For ground-water modeling, both the speed and the large memory of the CRAY-1 are beneficial. However, the program changes which have been completed do not take full advantage of either. Computational speed may be maximized only by restructuring (vectorizing) the computations to take advantage of the vector processing capability of the CRAY-1. Although the code described in this report has not been vectorized, execution on the CRAY-1 is cost effective. At the Kirtland Air Force Base facility, the transient example given below (800 nodes, 1463 iterations) was executed on Cyber 170 model 176 in about 0.0001 second for each node-iteration at a total cost of about 72 dollars in 1980. The same problem was executed on the CRAY-1 in about 0.00005 second for each node-iteration at a total cost of about 26 dollars in March 1981. The cost on the CRAY-1 at this time was about 0.00002 dollar per node-iteration.

The memory of the CRAY-1 installed at Kirtland Air Force Base allows an individual user to access up to 3.3 million octal words. To represent a 35,000 node model (7 layers of 5,000 nodes with 15 variables per node) requires about 2.7 million octal words, of which 2.0 million octal words are used for the array in which the three-dimensional variables are stored, and 0.7 million octal words are used for other arrays.

This memory is adequate for most ground-water simulations which are economically feasible. The cost of the 35,000-node problem described above (assuming 0.00002 dollar per node-iteration) would be about 0.7 dollar per iteration. At this rate, a simulation requiring 1,000 iterations would have cost about 700 dollars. Simulations requiring more nodes, which may be done by swapping the layers to and from a disk file, will be too costly for the development of most ground-water models. Although the computer code could be changed to reduce storage requirements, these changes have not been made.

USER'S GUIDE

Large parts of the original documentation (Posson and others, 1980) are repeated here to make this segment of the report a complete guide for the user. The only modifications are the order of presentation and any rewording required by the changes described above.

Equations of flow

If confining beds are thin relative to the vertical dimension of the cells of the model, each cell will represent several beds of both permeable and less permeable material. In the macroscopic scale of the model, the cell is homogeneous although possibly anisotropic. The flow field may be described by the equation for ground-water flow in three dimensions.

$$\frac{\partial}{\partial x}\left(K_x \frac{\partial h}{\partial x}\right) + \frac{\partial}{\partial y}\left(K_y \frac{\partial h}{\partial y}\right) + \frac{\partial}{\partial z}\left(K_z \frac{\partial h}{\partial z}\right) = S_s \frac{\partial h}{\partial t} + W\,(x,y,z,t) \qquad \text{(A)}$$

in which

K_x, K_y, K_z are the hydraulic conductivities in the x, y, and z directions (feet per second);

h is the hydraulic head (feet);

S_s is the specific storage (per foot); and

W is the volumetric flow per unit volume (per second).

This is equivalent to Trescott's equation 3 (Trescott, 1975, p. 3), and may be solved by the computer program.

Alternately, each layer may represent a separate hydraulic unit; equation A may be multiplied by the thickness of the hydraulic unit and expressed as:

$$\frac{\partial}{\partial x}(T_x \frac{\partial h}{\partial x}) + \frac{\partial}{\partial y}(T_y \frac{\partial h}{\partial y}) + b \frac{\partial}{\partial z}(K_z \frac{\partial h}{\partial z}) = S \frac{\partial h}{\partial t} + bW \quad (x,y,z,t) \quad (B)$$

in which

T_x, T_y are the transmissivities in the x and y directions (feet squared per second);

K_z is the hydraulic conductivity in the z direction (feet per second);

h is the hydraulic head (feet);

S is the storage coefficient (dimensionless);

b is the thickness of the hydraulic unit (feet); and

W is the volumetric flow per unit volume (per second).

This is equivalent to Trescott's equation 4 (Trescott and Larson, 1976, p. XV) and may be solved by the computer program.

The finite-difference approximation and the solution algorithm used by the computer program are described by Trescott (1975).

An aquifer system which consists of alternating well-defined layers of highly permeable and poorly permeable material requires special consideration if the confining beds are thick relative to the vertical dimension of the model's cells. Steady-state flow in such a system may be simulated with equation A or B. However, the transient or time-dependent flow through the confining beds is complicated by the storage properties of the confining beds.

The three-dimensional flow field may be approximately described by a sequence of equations for two-dimensional horizontal flow in each of the highly permeable beds coupled by the equations for one-dimensional vertical flow through the confining beds.

$$\frac{\partial}{\partial x}\left(T_x \frac{\partial h}{\partial x}\right) + \frac{\partial}{\partial y}\left(T_y \frac{\partial h}{\partial y}\right) = S\frac{\partial h}{\partial t} + bW(x,y,z,t) + Q_L(x,y,z,t) \quad \text{(C)}$$

in which

Q_L is the volumetric flow per unit area from the confining beds (feet per second); and the other variables are as defined for equation B.

The leakage between aquifers is augmented by the change in storage in the intervening confining bed. The release of this water is delayed by the time of propagation of the change in head vertically through the confining bed.

In water-table aquifers, transmissivity is a function of saturated thickness and hydraulic conductivity; the storage coefficient is the specific yield. The special computations of transmissivity and storage coefficient required by a combined water-table and artesian aquifer system (Trescott, Pinder, and Larson, 1976, p. 10-11) are included in the computer code. The water table may be represented in one of two manners. In one, the top layer of cells may represent the water table conditions (as in Trescott, 1975). In the other, the computer program allows each cell in the model to represent artesian or water-table conditions or to become permanently desaturated. A water table may be simulated using equation B if each cell represents several beds of both permeable and less permeable material, or by using equation C if each cell represents a unit of permeable material separated from similar material by a well-defined confining bed.

Boundary conditions

Specified-head, specified-flow, and head-dependent-flow boundaries may be represented using the computer program. Properties of boundaries may be represented as changing with time by dividing the total simulation into discrete intervals. In the following discussion the first echelon of subdivision (such as steady state, history, and projected future) are called stages. Each stage may be subdivided into pumping periods. Each pumping period is subdivided into time steps as described by Trescott (1975, p. II-3, III-8). Changes in properties of boundaries may be specified between time steps, pumping periods, or stages.

Specified head

A specified-head boundary is used to represent parts of the aquifer system where the head is constant over the time interval being simulated. The location or value of a constant-head boundary can be changed only through the restart option. The old values on the BAKIN file can be overwritten in 3D INPUT (block 7). At least one head should be specified for each simulation as a reference datum for the other heads.

Specified flow

Specified-flow boundaries are used to represent parts of the aquifer system where the flow rate is constant during the time interval being simulated. A no-flow boundary is a special case of the specified-flow boundary. The algorithm requires that the modeled area be surrounded by a no-flow boundary. Other boundaries may be specified within this shell.

Well withdrawal or injection is defined for each well as the flow rate (cubic feet per second) when solving equations B or C or the flow rate per unit thickness (feet squared per second) when solving equation A. The flow rate is constant for each pumping period of the simulation. For each well the location (row, column, and layer of the cell) is associated with a withdrawal rate (or appropriate weighting factor) and the index for the multiplying factor needed to convert to feet cubed (or squared) per second. For example, to represent withdrawal for irrigation, the weighting factor for a cell could be the number of irrigated acres in the cell and the multiplying factor could be used to calculate the cubic feet per second required for irrigation. The weighting factor (Q) and index (QTYPE) associated with each location remains the same throughout the simulation. However, the conversion factor (QFAC) may be redefined for each pumping period. In each node, the computer program accumulates the total rate of withdrawal or injection for all wells in the cell.

A specified rate of recharge may be represented in either of two ways. First, flow to the ground water is implied when the product of the weighting factor (Q) and the multiplying factor (QFAC) is positive. The volumetric flow rate (cubic feet per second) is recalculated for each pumping period.

Alternately, recharge may be defined in a two-dimensional array (QRE) as the volumetric flow per unit area (feet per second) to the upper layer of cells. The flow rate is constant for each stage of the simulation. On a restart, the old values on the BAKIN file can be overwritten in 2D INPUT (block 8).

Head-dependent flow

The flow at a head-dependent boundary node is calculated as shown in figure 1. The flow, QR, is calculated as

$$QR = (VK)(AREA)(RIVER - HA) \qquad (D)$$

in which

AREA is the surface area of the cell (feet squared);

VK is a constant of proportionality (per second);

RIVER is the value of simulated head at which there will be no flow to or from the ground water (feet); and

HA is the simulated head (feet).

Flow rates from the river to ground water (positive flow in fig. 1) are further restricted to be the lesser of the flow (QR) calculated by equation D, the maximum (QMAX) specified by the user, or the flow available in the stream (routed to this node from upstream nodes). Flow rates to the river from ground water (negative flow in fig. 1) are restricted to be less in absolute value than the maximum (QMXOUT) specified by the user.

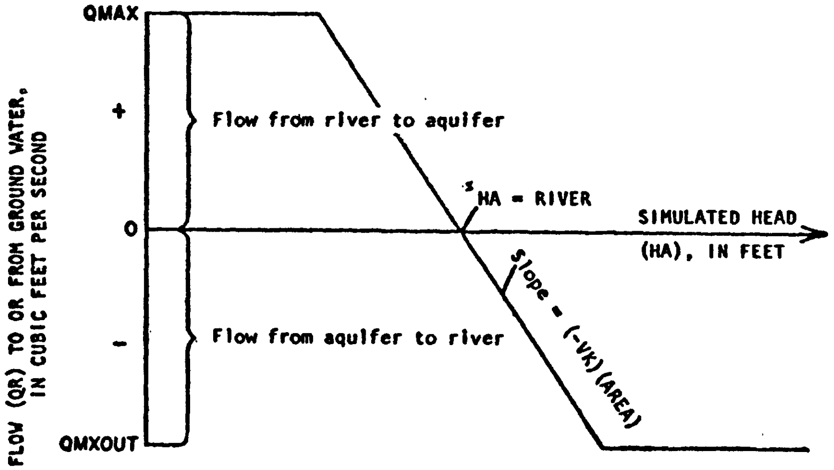

Figure 1. Function describing ground-water flow at a head-dependent flow boundary.

To represent a stream:

QMAX = maximum infiltration rate (cubic feet per second);
QMXOUT = maximum rate of discharge from ground water (cubic feet per second) (Although not physically meaningful, the program design requires a value be specified for QMXOUT to permit discharge to the river. This value should be selected large enough not to artificially restrict ground-water discharge to the river.);
RIVER = altitude of water in the river (feet) (Long-term average may be at or near the altitude of the stream bed.);
VK = (A')(LC); where
A' = fraction of cell area over which the stream bed occurs (dimensionless); and
LC = leakance coefficient (per second) (ratio of hydraulic conductivity to thickness of the streambed).

To represent evapotranspiration:

QMAX = 0;
QMXOUT = the maximum evapotranspiration rate (cubic feet per second) (QMXOUT = (QET)(Area of cell)); where
QET = maximum evapotranspiration rate (feet per second) for cells in which the head is at the land surface;
RIVER = LAND - ETZ; where
LAND = altitude of land surface (feet);
ETZ = depth below land surface at which exapotranspiration ceases (feet); and
VK = (A')(QET/ETZ) (per second); where
A' = fraction of the cell area over which evapotranspiration is represented (dimensionless).

The physical analogy for each of these variables depends on whether the boundary is being used to represent a stream or evapotranspiration. Evapotranspiration from ground water may be represented as a "stream" because the form of the equation specifying the dependence on head is identical. Whatever the form of recharge/discharge being represented, the variables are defined in terms of "streams". Each "reach" is "routed" or accumulated independently even though several "reaches" may pass through the same cell.

The remainder of this section details the function, format, and sequence of input records which may be submitted to compile and execute a program on the CRAY-1.

Compiling a program to execute on CRAY-1

This section provides information required to create and store a file of binary instructions on the Air Force Weapons Laboratory (AFWL) system disks. The control records are for the AFWL computer system and may need to be modified for other computer systems or in response to change in operation of the AFWL system.

Generally, a user desiring to run a simulation will only need to execute the instructions in this section once (successfully). When completed, the job sequence described below will have produced both a source file and a file of binary instructions tailored to the user's simulation and stored on a permanent disk file which may be loaded and executed repetitively without re-compiling.

Three steps are needed to produce binary instructions: (1) the Cyber utility UPDATE is used to produce the FLECS source, (2) the FLECS processor produces the FORTRAN source, and (3) the FORTRAN compiler produces the binary instructions. The input file for this 3-step process is shown in table 1. Upper-case letters are to be entered as shown. Lower-case letters identify fields which the user will define when submitting the job. Numbers in the left margin are for reference and are not part of the record. The source code for this program (OLDPL) is maintained on a permanent disk file at the AFWL computer center. Permanent files are accessible from CRAY-1 and the CDC mainframes at AFWL. The code is executed on the CRAY-1 computer.

Table 1. Job stream for compiling a program to execute on CRAY-1

```
1.  cdcjobname,T500,I0177,ST066.
2.  ACCOUNT,your accounting information.
3.  COMMENT.*******************************
4.  COMMENT.THIS JOB ATTACHES CRAPL,
5.  COMMENT.     DOES AN UPDATE(Q,D,K,L=A13)
6.  COMMENT.     FLECS THE RESULTANT COMPILE FILE
7.  COMMENT.     CREATES AN INPUT DECK FOR CRAY-1
8.  COMMENT.     CATALOGED AS firstpfn,ID=yourid
9.  COMMENT.     COMPILES THE CODE ON CRAY-1
10. COMMENT.     SAVES THE EXECUTABLE BINARIES
11. COMMENT.     AS secondpfn, ID=yourid ON MFA/MFB
12. COMMENT.********************************
13. ATTACH,OLDPL,CRAPL,ID=yourid.
14. UPDATE(Q,D,K,L=A13).
15. RETURN,OLDPL.
16. ATTACH(FLECS).
17. REQUEST,INCRA,*PF.
18. FLECS(COMPILE).
19. RETURN(FLECS,COMPILE).
20. COPYBR,INPUT,INCRA.
21. COPYBF,FOUT,INCRA.
22. CATALOG,INCRA,firstpfn,ID=yourid,RP=999.
23. ZAP,INCRA,tid,,IN.
24. $EOR
25. *ID anyname
26. *COMPILE SIPMN.ENDMN,SIPCM.ENDCM,SIPIN.ENDIN
27. *DEFINE rrcc 28. *DEFINE PLxxxxx
29. *DEFINE NCHxxxx
30. *DEFINE NWxxxx
31. *DEFINE MODExxxxx
32. *DEFINE NHGxx
33. *DEFINE OBSHYD
34. *DEFINE NSYMxxxx
35. *DEFINE WSUR
36. *DEFINE RECH
37. *DEFINE RIVERS
38. *DEFINE NRxxx
39. *I MODEF.7
40.       COMMON/L3STOR/STRLCM(xxxxx)
41. $EOR
42. crayjobname,T100,I010,STCRA.
43. ACCOUNT,your accounting information.
44. JOB,T=100
45. COPYD,I=$IN,O=SOUR.
46. RELEASE,DN=$IN.
47. REWIND,DN=SOUR.
48. *.     COMMENT      SOUR IS THE FORTRAN SOURCE CODE
49. CFT,I=SOUR.
50. REWIND,DN=$BLD
51. COPYD,I=$BLD,O=BLD.
52. REWIND,DN=BLD.
53. *.       COMMENT     BLD IS THE EXECUTABLE BINARIES
54. DISPOSE,DN=BLD,SDN=secondpfn,ID=yourid,RP=999,DC=ST,DF=TR.
55. EXIT.
56. $EOF
```

CDC control block: Records 1 through 24

The first 2 steps of the 3-step procedure are done on the CDC-6600.

Record 1 is the system jobcard which identifies your job to the system by name and defines certain limits on system resources. The first field is the jobname which may be from 1 to 20 alphanumeric characters. The first 3 characters will be assigned to the user by the system librarian at AFWL when an account is established.

Record 2 is the ACCOUNT command which provides accounting information to the system to allow billing for the computer time used by a job. An account number will be given by AFWL when an account is established.

Records 3 through 12 are CYBER COMMENTS which are not executable. Comments are optional. Use as many as necessary. Comments are displayed in the job dayfile.

Record 13 attaches the master program library which contains all source statements for the program. The Cyber utility UPDATE will read this file and generate another file which contains only those source statements selected by user-defined options.

Record 14 loads the Cyber UPDATE utility program and begins execution. UPDATE will read the instructions defined in the UPDATE control block (records 25 through 41). Input is the file OLDPL which was attached in record 13. The set of statements selected by UPDATE is written to a file named COMPILE.

Record 15 detaches the OLDPL from the job and returns it to the system.

Record 16 attaches the FLECS structured FORTRAN processor to the job.

Record 17 informs the system that file INCRA is to be a permanent file.

Record 18 loads the FLECS structured FORTRAN processor and instructs it to read the statements located on the COMPILE file. FLECS produces a formatted listing on the printer output file and a file named FOUT. FOUT contains FORTRAN statements which will be processed by the CRAY-1 FORTRAN compiler, CFT.

Record 19 detaches the FLECS and COMPILE files from the job and returns them to the system.

Record 20 copies the INPUT control block (cards 42 through 55) to the file INCRA.

Record 21 copies the file FOUT to the file INCRA. The file INCRA now contains the FORTRAN source code (FOUT) preceeded by the control statements (records 42 through 55) needed to compile the program on CRAY-1 and store the executable binaries as a permanent file on the CDC-6600.

Record 22 tells the system to store the file INCRA as a permanent file.

Record 23 places the file INCRA in the INPUT queue with OUTPUT to be routed to the terminal where the identification code is "tid."

Record 24 marks the end of the CDC job control block and the beginning of the UPDATE control block.

UPDATE control block: Records 25 through 41

This block follows immediately after the end-of-record at the end of the CDC control block. The user defines those options and subprograms that the Cyber UPDATE utility is to select from the statements residing on the OLDPL file. The text selected by UPDATE is written to the COMPILE file.

Update identification (record 25 - optional)

The first record of the update control block provides a name for the changes implemented by this UPDATE. This record is optional.

Update sequence (record 26)

The second record of the UPDATE control block must be:

```
*COMPILE SIPMN.ENDMN,SIPCM.ENDCM,SIPIN.ENDIN
```

This record starts in column one. It tells UPDATE to write the SIP main overlay to COMPILE first, followed by the SIP computational overlay, and then the SIP data-input overlay.

Next, the user must define those options which UPDATE is to take into account when writing the COMPILE file. Included in this section are definitions for the number of rows, columns, and layers, together with other "sizing" parameters. The user will define the UPDATE options using the generalized format:

```
*DEFINE option
```

coded in column one of each record. Each *DEFINE command will cause certain conditional source statments to be entered into the COMPILE file by UPDATE. In this manner, the source code is tailored to the requirements of this simulation. Some of the program options will use defaults if no *DEFINE command is entered. For others, the user must select one of the available *DEFINE commands, identified on pages 15 through 21.

Row and column dimensions (record 27)

The number of nodes in the row and column directions must be defined. UPDATE will generate various arrays based on these dimensions. The code is designed to allow the selection of any number of rows and columns, in multiplies of five, from 10 to 95. For example, if a model is 23 rows by 37 columns, the user should define a grid which is 25 by 40. The minimum dimension is 10 by 10 and the maximum is 95 by 95. One and only one option must be defined. Note that simulations using smaller numbers of rows or columns may be run on code compiled with a larger number of rows or columns. However, the converse is not true. Obviously, the larger number of rows and columns defined, the more memory the program will require. Thruput and cost may be affected as a result.

The generalized format for this option is:

*DEFINE rrcc

where: rr is a two digit number from 10 to 95 inclusive indicating the number of rows. rr must be a multiple of 5.
cc is a two digit number from 10 to 95 inclusive indicating the number of columns. cc must be a multiple of 5.

Number of words per layer (NWPL) (record 28)

The program performs many of its internal operations on complete layers. It stores a fixed number of words per layer, depending on the number of rows (NROW), columns (NCOL), and variables per node (NVPN). The user must multiply these three numbers together, round the result up to the next larger multiple of 1,000 and define that value for UPDATE. For example, if a model is 23 rows by 37 columns, the number of nodes per layer is 851. If the number of variables per node (NVPN) is 15, then the number of words per layer (NWPL) is 12,765. A value of 13,000 should be specified for UPDATE.

The generalized format for this option is:

*DEFINE PLxxxxx

where: xxxxx is the number calculated as described above. The number may be a minimum of 1,000 and a maximum of 99,000. If the number is less than 5 digits, use only the first 4 xxxxx positions. No commas may be embedded in xxxxx.

Maximum number of specified-head nodes (record 29)

The program keeps track of the location of and the net flow to or from each specified-head node. The user must determine the maximum number of specified-head nodes which will exist in the model, and enter the appropriate option.

The generalized format for this option is:

*DEFINE NCHxxxx

where: xxxx is the maximum number of specified-head nodes allowed in the model. xxxx may be 100, 200, 300, 400, 500, 1,000, 1,500, 2,500, or 3,000. No commas may be embedded in xxxx.

Maximum number of active wells (record 30)

The program maintains various arrays pertaining to the location of and quantities being pumped from individual wells. The user must determine the maximum number of wells to be used and enter the appropriate option.

The generalized format for this option is:

*DEFINE NWxxxx

where: xxxx is the maximum number of pumping wells. xxxx may be 100, 200, 300, 400, 500, 750, 1,000, or 2,000. No commas may be embedded in xxxx.

Transient leakage exponential terms (record 31)

If the user intends to use the program with TRLEAK=.TRUE. for transient leakage from confining layers, then he must determine the size of the array to be allocated in subroutine CLAY. The size equals the number of rows times the number of columns times the number of "modes", where "mode" is the number of exponential terms to be used. The user must round this number up to the next higher multiple of 1,000 and enter the appropriate option. If transient leakage is not to be used, enter the option with a value of 100.

The generalized format for this option is:

*DEFINE MODExxxxx

where: xxxxx is the result of the multiplication described above. xxxxx may have any value from 1,000 to 20,000, and must be a multiple of 1,000. If transient leakage is not to be used, xxxxx = 100. No commas may be embedded in xxxxx.

Although MODE allocates space in subroutine CLAY, disc file space must also be allocated in data input block 1. That is done by activating the transient-leakage cards in the job stream shown in block 1.

Maximum number of hydrograph plots (record 32 - optional)

The user may have the program produce head versus time or drawdown versus time hydrograph plots at any node in the model. The maximum number of hydrographs must be defined by this option. If observed hydrographs are also to be plotted, the user must also define the OBSHYD option.

The generalized format for this option is:

*DEFINE NHGxx

where: xx is the maximum number of hydrograph plots. xx may have the values 10, 20, 30, or 40. If no hydrographs are to be produced, xx = 10.

Observed hydrograph plots (record 33 - optional)

The user may choose to enter observed hydrograph data into the model. The program will plot the observed values on the same axis as the calculated values for the selected nodes. If observed hydrographs are to be produced, this option must be defined.

To select this option:

```
*DEFINE OBSHYD
```

Maximum number of list/map output cubes (not in table 1 - optional)

Data which is read in data input block 9 define cubes for which list and/or map output is to be produced. This option is used to define memory allocated to the arrays which are used to support output cubes.

The generalized format for this option is:

```
*DEFINE NCUxxx
```

where: xxx is the maximum number of output cubes. xxx may only have the value 100. If this option is not selected, 50 will be the maximum number of output cubes by default.

Maximum number of symbol-value pairs (record 34)

Program DATAIN allocates memory for storing the user-defined symbol-value pairs in data input block 6. The maximum number of symbol-value pairs must be defined with this option. The same maximum applies to the total number of records used for cube input in data input blocks 7, 8, and 9. For a given simulation the actual limit will be the smaller of NSYM or the quotient NVPL/20. NVPL (number of variables per layer) is the product of the number of rows (NROW) times the number of columns (NCOL) times the number of variables per node (NVPN) as defined in data input block 4 below.

The generalized format for this option is:

```
*DEFINE NSYMxxxx
```

where: xxxx may have the values 200, 400, or 1,000. No commas may be embedded in xxxx.

Water-table problems in two dimensions (not in table 1 - conditional)

The program allows the use of two different water-table options. All water-table nodes may reside in the top layer or water-table nodes may reside in any of the model layers. The latter is the program default. If the user restricts water-table conditions to the top layer, then both BOT (the bottom elevation of the water table layer) and PERM (the hydraulic conductivity of the unconfined cells) are treated as two-dimensional variables. Otherwise, they are carried as three-dimensional variables.

To restrict water-table conditions to the top layer,

```
*DEFINE 2DBTPRM
```

Unconfined water surface lists and/or maps (record 35)

If using three-dimensional water-table conditions, this option is recommended. If the user defines RIVERS, this option is mandatory. When selected, it will allow the printing of lists and/or maps of the unconfined water surface. The array WSUR will be maintained by the program for this purpose.

To select this option:

```
*DEFINE WSUR
```

Areal recharge to the top layer (record 36)

The selection of this option will allow the recharge term, QRE, to be included in the model.

To select this option:

```
*DEFINE RECH
```

Head-dependent flow boundaries (record 37)

If using the program's head-dependent flow boundaries this option must be selected. When selected, the user must also define WSUR and dimension the necessary arrays as described on the next page.

To select this option:

```
*DEFINE RIVERS
```

Dimension arrays for head-dependent flow boundaries (record 38)

If using head-dependent flow boundaries, memory must be allocated for the appropriate arrays. The user must determine the maximum number of head-dependent flow nodes and the maximum number of reaches into which they will be grouped. The set of activated dimensions must be large enough to accommodate both.

The generalized format for this option is:

```
*DEFINE NRxxx
```

where: Ten times xxx is the maximum number of river nodes and xxx is the maximum number of river reaches. xxx may be 10, 20, 30, 40, 50, 75, 100, 150, 200, or 300.

Dimension array for three-dimensional variables (records 39 and 40)

The program stores all of the three-dimensional variables in a one-dimensional array. This array must be dimensioned by the user to equal or exceed the number of words in all layers. The user must multiply the number of rows times the number of columns times the number of layers times the number of variables per node to calculate the number of decimal words in all layers. For example, if a model is 23 rows by 37 columns by 7 layers with 15 variables per node, then the number of words in all layers is 89,355.

The generalized format to dimension this array requires the two records:

```
*I MODEF.7

      COMMON/L3STOR/STRLCM(xxxxx)
```

The first record starts in column 1 and instructs UPDATE to insert the second record following the seventh record in the MODEF COMDECK.

The second record starts in column 7 and dimensions the array STRLCM. xxxxx must equal or exceed the number of decimal words in all layers.

Record 41 marks the end of the UPDATE control block and the beginning of the CRAY-1 control block.

CRAY-1 control block: Records 42 through 56

The following records preceed FOUT on the INCRA file. When INCRA is executed on CRAY-1, an executable load module is created and stored.

Record 42 is the first card in the file INCRA and identifies the job to the system. Format is similar to that for record 1.

Record 43 provides accounting information and is identical to record 2.

Record 44 is the jobcard for the CRAY-1 operating system (COS).

Records 45 through 47 copy the FORTRAN source code to the file SOUR.

Record 48 is a CRAY-1 comment which is optional and not executable. Comments are displayed in the CRAY-1 dayfile.

Record 49 compiles the FORTRAN source code (FOUT) producing a listing on the printer output file and a file of binaries on $BLD.

Records 50 through 52 copy the binaries to the file BLD and rewinds the file.

Record 53 is a CRAY-1 comment record.

Record 54 catalogs the binaries as a permanent file on CDC.

Record 55 terminates the CRAY-1 control block.

Record 56 terminates the job stream and is not written on the INCRA file.

Program input requirements

This section details the function, format, and sequence of input records which may be submitted to the program. The control cards are for the computer system at the Kirtland Air Force Base, Air Force Weapons Laboratory (AFWL), and may need to be modified for other computer systems or in response to changes in operation of the AFWL system.

Decks are discussed as being divided into 13 input blocks, each of which serves a different purpose. Blocks 5, 6, 7, 8, and 9 are optional. However, block 6 must preceed blocks 7, 8, and 9. Blocks 2, 4, 11, 12, and 13 use the "NAMELIST" format (Posson and others, 1980, p. 51). These blocks must contain at least $NAME and $END where NAME is the name of the NAMELIST.

Data input block 1: Program execution

Programs can be executed on CRAY-1 with job streams that are either on a CDC permanent file or on a HARRIS disk file. A generalized job stream is shown in table 2 as it might occur on a CDC permanent file. The job stream could be executed with the commands:

```
ATTACH,A,filepfn,ID=yourid.

BATCH,A,INPUT,tid.
```

where tid is the identification code for the terminal to which output is to be routed.

Some of the records in table 2 are needed only if the simulation includes transient leakage (TRLEAK = .TRUE.,), a BAKIN file is read (RESTRT = .TRUE.,), a BAKOUT file is written (SELRES = .TRUE.,), or a META file is written (maps or hydrographs). For the example shown in table 2 TRLEAK = .FALSE., RESTRT = .FALSE., SELRES = .FALSE., and a META file is written. For the conditional records which are not to be active, the records have been made comment records by placing "*." in the first two columns. These records would be executed if the "*." were removed. If a simulation is to create a BAKOUT file (SELRES = .TRUE.,), the "*." should be removed from the two records following the comment to "CATALOG BAKOUT". If a simulation is to restart from a previous condition (RESTRT = .TRUE.,), the "*." should be removed from the three records following the comment to "ACQUIRE THE BAKIN FILE". For many simulations, both BAKIN and BAKOUT files will be used; both sets of records should be activated by removing the "*."

Table 2. Job stream for executing a program on CRAY-1 with the data input on a CDC permanent file

```
crayjobname,T177,I010,STCRA.
ACCOUNT,your accounting information.
JOB,T=177.
*.     ACQUIRE THE EXECUTABLE BINARIES                      ***************
ACQUIRE,DN=BLD,PDN=secondpfn,ID=yourid,DF=TR,UQ.
DELETE,DN=BLD.
RELEASE,DN=$IN.
*.     ACQUIRE THE DATA DECK                                ***************
ACQUIRE,DN=FT05,PDN=datainputpfn,ID=yourid,UQ.
DELETE,DN=FT05.
*.     SET UP FILE FOR TRANSIENT LEAKAGE - IF TRLEAK=.T.       ************
*.ASSIGN,DN=LTRFIL,A=FT41,RDM,BS=44.
*.WRITEDS,DN=LTRFIL,NR=2,RL=1620.
*.     WHERE NR=2X(NLAYER-1)     2X(2-1)=2
*.     RL=MODE X NROW X NCOL     5X18X18=1620.
*.     ACQUIRE THE BAKIN FILE - IF RESTRT=.T.               ***************
*.ACQUIRE,DN=FT03,PDN=bakinpfn,ID=yourid,DF=TR,UQ.
*.ASSIGN,DN=FT03,A=BAKIN.
*.DELETE,DN=FT03.
*.     LOAD EXECUTABLE CODE AND EXECUTE ON DATA             ***************
LDR,LIB=METALIB,SET=ZERO,DN=BLD.
*.     ROUTE THE META FILE OUT TO TERMINAL - IF META OUTPUT       *********
ACCESS,DN=DIRECT.
DIRECT,I=FT99,DEV=PRINTER.
*.     CATALOG BAKOUT AS A PERMANENT FILE ON CDC - IF SELRES=.T.      *****
*.REWIND,DN=FT04.
*.DISPOSE,DN=FT04,backoutpfn,ID=yourid,RP=999,DC=ST,DF=TR,WAIT.
AUDIT,ID=yourid.
EXIT.
$EOF
```

The job stream in table 2 assumes that the binaries have been created by a job stream like that in table 1. The "secondpfn" of table 2 is the "secondpfn" cataloged in table 1 (card 54).

The job stream of table 2 further assumes that data input blocks 2 through 13 are on a permanent file cataloged as "datainputpfn" under your identification code.

A generalized job stream is shown in table 3 as it might occur on a HARRIS disk file. The job stream could be executed by entering it into the queue for remote job entry (RJE) to KAFB.

The job streams for execution are unavoidably dependent on both hardware and software availability. As computer systems change, the job streams of tables 2 and 3 will become absolete. However, they are included here to indicate the general functions which must be performed.

Data input block 2: NAMELIST $CONTROL

Block 2 input is a set of logical switches which the user may define to control the selection of various program options. Each switch may be set to a logical .TRUE. or a logical .FALSE. within this block. The user may set any combination of these switches. The switches set in this block are not saved from previous simulations using the restart procedures. Thus, switch settings are used only for the duration of the one run in which they are defined. They are in NAMELIST format so the first record is $CONTROL starting in column 2 and the last record is $END starting in any of columns 2-77. The $CONTROL and $END records are always required. The order of input of the switches is unimportant, but they are grouped by function for this discussion.

Table 3. Job stream for executing a program on CRAY-1 through remote job entry (RJE) of a disk file on the HARRIS minicomputer

```
cdcjobname,T177,I0177,ST066.
ACCOUNT,your accounting information.
COMMENT.    COPY DATA TO A PERMANENT FILE ON CDC                ***************
REQUEST,DATA,*PF.
COPYBR,INPUT,DATA.
PURGE,OLDDATA,datainputpfn,ID=yourid,NA=1,LC=1.
RETURN,OLDDATA.
CATALOG,DATA,datainputpfn,ID=yourid,RP=999.
COMMENT.    COPY CRAY CONTROL DECK TO A PERMANENT FILE ON CDC   **********
REQUEST,INCRA,*PF.
COPYBR,INPUT,INCRA.
PURGE,OLDRUN,craypfn,ID=yourid,NA=1,LC=1.
RETURN,OLDRUN.
CATALOG,INCRA,craypfn,ID=yourid.
COMMENT.    ZAP FILE TO CRAY FOR EXECUTION                      ***************
ZAP,INCRA,tid,,IN.
$EOR
Data input blocks 2 through 13 go here
$EOR
Job stream shown in table 2 goes here
```

The first set of switches control the restart logic of the program. The user may restart from previous simulations using file BAKIN. The user may generate a file BAKOUT from which subsequent simulations may restart. When restarting, various options are available to the user.

SWITCH	DEFAULT	USE
RESTRT	.FALSE.	Restart this simulation from a previously run simulation. When set to .TRUE., the LFN named BAKIN will be read, initializing all matrices and program COMMON blocks to the values which pertained at the end of the earlier simulation. BAKIN resides on a disk permanent file, and ACQUIRE, ASSIGN, and DELETE cards must be defined for BAKIN (FT03) in input block 1. This simulation will restart at a new pumping period. The number of the new pumping period is independent of the number of the pumping period in the simulation which created the file named BAKIN.
RECMPL	.FALSE.	The program has been recompiled, or the matrices are to be completely redefined. This switch is only active when RESTRT=.TRUE. When RECMPL=.TRUE., all data other than the 3D array (input block 7) must be redefined. This switch must be set to .TRUE. if both RESTRT=.TRUE. and the program BLD has been recompiled since the BAKIN file to be used for this restart was created.
SELRES	.FALSE.	Select restart output. When SELRES=.TRUE., this simulation will create the LFN named BAKOUT (FT04) at the end of the run. BAKOUT will contain all model COMMON blocks and all matrices as of the end of the simulation. This file may be saved as a permanent file by including the REWIND and DISPOSE cards for BAKOUT (FT04) in input block 1. This switch should be .TRUE. if the results from this simulation are to be used as the basis for a future simulation. It should be noted that SELRES=.TRUE. and RESTRT=.TRUE. may be used in any combination within any one simulation. A run may be a restart from an earlier run; it may be the basis for a subsequent run; it may be both; or it may be neither.

The next set of switches may be used during any run regardless of how the restart switches are set.

SWITCH	DEFAULT	USE
ZRMBAL	.FALSE.	Zero out mass balance cumulative totals prior to beginning this simulation. This switch is normally used only when RESTRT=.TRUE. and when the mass balance totals calculated in the previous run should be ignored by this simulation. For example, if the prior run was a steady-state run and this is to be a transient run, earlier mass balance calculations may be ignored.
PHISET	.FALSE.	Set starting head values (STRT) to the values for head (PHI) before starting the simulation. This switch is useful in conjunction with RESTRT=.TRUE. to initialize the starting heads to the current heads; thus, drawdown calculations at the end of this simulation will be based on the heads at the start of this simulation.
DMPINT	.FALSE.	Dump input data arrays. By setting this switch to .TRUE., the user requests the program to produce a formatted listing of the data matrices for all nodes in the grid as soon as array initialization is complete and before the simulation begins. This switch may be used in conjunction with ONLYIN=.TRUE.
ONLYIN	.FALSE.	Only in. When ONLYIN=.TRUE., the program will terminate after the data matrices have been initialized, but before any simulation occurs. This switch when used in conjunction with DMPINT=.TRUE. allows the calculation of TR, TC, and TK, and is useful for checking the simulation input prior to simulation. Please note that ONLYIN=.TRUE. will not produce a BAKOUT tape even if SELRES=.TRUE.

The other switches described in the original documentation (Posson and others, 1980) are still available. However, they are not repeated here because the author has not found them useful.

Data input block 3: I/O control record

This block is required only when either RESTRT or SELRES, as defined in input block 2, is .TRUE.

Block 3 consists of one record. This record serves no purpose in the CRAY-1 version but is a vestige from the CYBER code. This record may contain any text or may be blank. This record was retained so that the same data deck (blocks 2-13) could be read by programs on either CYBER or CRAY-1.

Data input block 4: NAMELIST $INLIST

Block 4 inputs single-valued variables and one-dimensional arrays. The values of block 4 variables need not be respecified for a restart (RESTRT=.TRUE.) unless it is desired to change them or the program has been recompiled (RECMPL=.TRUE.). They are in NAMELIST format (Posson and others, 1980, p. 51) so the first record is $INLIST starting in column 2, and the last record is $END starting in any of columns 2-77. The $INLIST and $END records are always required. The order of input of the variables is unimportant, but they are grouped by function for this discussion. Variables relating to options are first, then variables relating to convergence, anisotropy, grid definition, pumpage, rivers, and output follow.

Variables associated with options are:

VARIABLE	DEFAULT	USE
EQN3	.FALSE.	When .TRUE., the program will solve equation A (equation 3 of Trescott, 1975). This requires that T (block 7) be input as hydraulic conductivity (feet per second), S (block 7) be input as specific storage (per foot), Q (block 12) be input as specific discharge (cubic feet per second per foot of aquifer thickness; or simply feet squared per second), and QRE (block 8) be input as specific discharge per unit area of land surface (cubic feet per second per foot of aquifer thickness per square foot; or simply per second). EQN3 and EQN4 cannot both be .TRUE. for the same simulation.

VARIABLE	DEFAULT	USE
EQN4	.FALSE.	When .TRUE. the program will solve equation B (equation 4 of Trescott, 1975, as corrected by Trescott and Larson, 1976) or equation C. Equation C is solved when transient leakage is used (TRLEAK=.TRUE.); otherwise, equation B is solved. EQN4 must be .TRUE. if either transient leakage or water table (WTABLE=.TRUE.) are used. This requires that T (block 7) be input as transmissivity (feet squared per second), S (block 7) be input as storage coefficient (dimensionless), Q (block 12) be input as discharge (cubic feet per second), and QRE (block 8) be input as discharge per unit area of land surface (feet per second).
RCHRG	.FALSE.	Recharge. RCHRG=.TRUE. indicates that the QRE array (block 8) will be used to represent recharge to some or all of the top layer.
MBALPR	.TRUE.	Mass balance printout. MBALPR=.TRUE. indicates that a mass balance printout is desired. This is almost always useful.
TRLEAK	.FALSE.	Transient leakage. When .TRUE., equation C is solved. (The analytical approximation for flow from confining beds is used to couple two-dimensional equations for aquifers). TRLEAK=.TRUE. requires that EQN4=.TRUE.
WTABLE	.FALSE.	Water table. WTABLE=.TRUE. calls for simulation of a water table which may exist in all layers or only in the top layer depending on how the program was compiled. WTABLE=.TRUE. requires that EQN4=.TRUE.

The use or value of certain variables depends on the options chosen above. They are:

VARIABLE	DEPENDS ON	USE
SY	WTABLE=.TRUE.	Specific yield is required only when WTABLE=.TRUE. SY is a one-dimensional array with one term (dimensionless) for each layer in the model, and the first term is associated with layer 1, the bottom layer. For simulation of a water table only in the top layer, the value SY must have a subscript equal to the number of layers, NLAYER.
SS	TRLEAK=.TRUE.	Specific storage of the confining bed(s) is required only when TRLEAK=.TRUE. SS is a one-dimensional array with one term (per foot) for each layer of the model except the top layer. The first value applies to the confining bed overlying layer 1, the bottom layer.
MODE	TRLEAK=.TRUE.	The number of terms to be used in the memory and influence functions (Posson and others, 1980, p. 10) of the confining bed approximations is required only when TRLEAK=.TRUE. Usually a value between 3 and 7 is adequate with the large values requiring more computer storage and producing more accurate results.
NVPN	WTABLE and TRLEAK, and 2DBTPRM	Number of 3D array variables (block 7) per node. To minimize computer storage, select the smallest value of NVPN compatible with the simulation. The user must specify one of the 4 values as indicated in table 4.

Table 4. Number of 3D array variables per node (NVPN)

WTABLE TRLEAK	.TRUE.		.FALSE.
	Water table in all layers	Water table in top layer only*	
.TRUE.	NVPN = 20	NVPN = 18	NVPN = 18
.FALSE.	NVPN = 15	NVPN = 13	NVPN = 13

*Program compiled with 2DBTPRM defined.

Variables associated with convergence are:

VARIABLE	DEFAULT	USE
CLSURE	0	Closure criterion: The simulation proceeds to the next time step if the head change during the last iteration is less than CLSURE at all nodes. This variable must be specified for an initial run (RESTRT=.FALSE.). Typical values are .01 or .001 foot.
ITMAX	0	Maximum number of iterations per time step: The simulation is terminated if ITMAX iterations have been completed and the maximum head change still exceeds CLSURE. If SELRES=.TRUE. (block 2) a BAKOUT file will be written using PHI from the last time step. This variable must be specified for an initial run (RESTRT=.FALSE.). The value may be as large as 200, but values between 25 and 100 are typical.
NRHØP	0	Number of iteration parameters. This is the LENGTH variable from Trescott (1975). A number between 1 and 20 is allowed; 5 is usually satisfactory.
RHØP	Conditional	Iteration parameters: RHØP is a one-dimensional array of length NRHØP, which is normally calculated from WMAX by the program as in Trescott (1975). After some experience with a specific model, the modeler may decide that convergence can be achieved more quickly by specifying RHØP. If values of RHØP are specified (or retained on the BAKIN file of a restart), the routine to calculate it is ignored and so is the value of WMAX (next page).

VARIABLE	DEFAULT	USE
WMAX	Conditional	Maximum iteration parameter: When allowed to default, the program calculates a WMAX to use in calculating parameters unless they are specified as RHOP (above). The resulting iteration parameters may lead to slow convergence especially when WMAX approaches 1.000. The user may influence the calculation of the iteration parameters by defining a non-zero WMAX. WMAX = .999 may be satisfactory.
DAMP	1	Damping factor: The residual term (known from the source term and the heads of the previous iteration, Trescott, 1975, p. 12) is multiplied by DAMP. Values of DAMP greater than 1 will cause a greater head change and may accelerate convergence if the undamped head change is very small. Values of DAMP less than 1 may accelerate convergence if the undamped head changes are oscillating. A value of 1.0 (i.e., no damping) is usually satisfactory. Values less than 0.5 or greater than 1.5 may be unsatisfactory.

Variables associated with anisotropy are:

VARIABLE	DEFAULT	USE
FACTX	0,0,,,,.0	Anisotropy factors for the x direction: FACTX is a one-dimensional array with one term for each layer. The first term is associated with layer 1. The coded value of T (transmissivity or hydraulic conductivity) is multiplied by this value in the calculation of TR (block 7) before the flow equations are solved. Except for water-table calculations, FACTX is not used for those cells where TR is non-zero; thus, nonuniform anisotropy can be simulated for confined cells by specifying TR directly in block 7 for all or part of the model. Note that on a restart the previous TR value is on the BAKIN file; A new TR value will be calculated only if the previous value is overwritten with zero in block 7.
FACTY	0,0,...,0	Anisotropy factors for the y direction: FACTY is used in the calculation of TC (block 7) in the same way that FACTX is for TR.

VARIABLE	DEFAULT	USE
FACTZ	0,0,...,0	Anisotropy factors for the z direction: FACTZ is used in the calculation of TK (block 7). If EQN3=.TRUE., then FACTZ is the ratio (K'/K) of vertical hydraulic conductivity to horizontal hydraulic conductivity. If EQN4=.TRUE., then FACTZ is the ratio (K'/T) of vertical hydraulic conductivity to transmissivity. FACTZ is not used for those cells where TK is nonzero; thus, nonuniform anisotropy can be simulated by specifying TK directly in block 7 for part of the model. Note that on a restart the previous TK value is on the BAKIN file; a new TK value will be calculated only if the previous value is overwritten with zero in block 7. FACTZ is not used if the transient leakage equation (C) is solved (TRLEAK=.TRUE.).

Variables associated with grid definition are:

VARIABLE	USE
NROW	Number of rows in the y direction.
NCOL	Number of columns in the x direction.
NLAYER	Number of layers in the z direction.
DELX	Grid spacings in the x direction (feet).
DELY	Grid spacings in the y direction (feet).
DELZ	Grid spacings in the z direction (feet).

The origin is located in the upper left corner of the bottom layer as in Trescott (1975). NROW tells how many terms are in the DELY vector, and NCOL tells how many terms are in the DELX vector. Layers are counted from bottom to top; layer 1 is the bottom and NLAYER is the top.

The grid is block centered; the node points fall midway between the sides of the cells.

Variables associated with pumpage are:

VARIABLE	DEFAULT	USE
NPER	0	Number of pumping periods: NPER is the number associated with the last pumping period to be simulated by this run. KP, input in block 11, specifies the number associated with the current pumping period. Simulation stops after completion of the pumping period where KP is greater than or equal to NPER.
QFAC	1,1,...,1	Discharge multiplying factors: QFAC is a one-dimensional array of 100 conversion factors used to convert flow rates from convenient units to consistent units (cubic feet per second if EQN4=.TRUE. or feet squared per second if EQN3=.TRUE.). QFAC is used in conjunction with QTYPE (block 12) where the first term of QFAC is associated with QTYPE=1, the second term with QTYPE=2, etc. QFAC has 100 terms. If any Q (block 12) is converted to consistent units before it is input, then QTYPE (block 12) may be allowed to default to 100 thus utilizing QFAC (100) which defaults to 1.

Variables associated with head-dependent flow boundaries are:

VARIABLE	USE
NR	Number of river reaches: A river reach is defined such that surface flow into a river reach may occur only at the most upstream node of the reach, and surface flow out may occur only at the most downstream node of the reach. NR may be altered each pumping period (block 13) if desired. NR has a maximum value defined when the program is compiled. Arrays NRC, RQ, and NADD each have NR terms.
NRC	Number of nodes in each river reach: NRC is a one-dimensional array with NR terms. The terms must be entered in the order in which the river reaches are to be calculated. If river reach A discharges to river reach B, then reach A must be calculated before reach B. The maximum number of river nodes allowed is defined when the program is compiled. NRC may be altered each pumping period (block 13) if desired.

VARIABLE	USE
RQ	Flow (cubic feet per second) into each river reach from outside the model: RQ is a one-dimensional array with NR terms. The terms are in the same order as in NRC. RQ flow can only be specified at the most upstream node of each river reach. RQ may be altered each pumping period (block 13) if desired.
NADD	The destination for outflow from each river reach: NADD is a one-dimensional array with NR terms. Terms are in the same order as in NRC. The first term gives the destination (reach number) of surface flow from the first reach calculated. If flow from any reach is not to be added to another reach, its destination is zero. The total flow into a downstream reach is the sum of the RQ flow for that reach and the outflow from any upstream reaches. NADD may be altered each pumping period (block 13) if desired.
INDX	Location of river nodes: INDX is a one-dimensional array with two terms for each river node. The terms are in the order in which the river nodes are to be calculated. The first two terms of INDX are the row and column, respectively, of the most upstream node of the first river reach to be calculated. The last two terms of INDX are the row and column of the most downstream node of the last river reach to be calculated. The order of river reaches is the same as in NRC.
RIVER	Altitude (feet) of the river at each river node: RIVER is a one-dimensional array with one term for each river node. The terms are in the order in which the river nodes are to be calculated. Thus, the first term is for the most upstream node of the first river reach to be calculated and the last term is for the most downstream node of the last river reach to be calculated.
VK	Leakance coefficient (per second): VK is a one-dimensional array with one term for each river node. The terms are in the same order as in RIVER.

VARIABLE	USE
QMAX	Maximum infiltration rate (cubic feet per second): QMAX is a one-dimensional array with one term for each river node. The terms are in the same order as in RIVER.
QMXOUT	Maximum rate of flow from ground water (cubic feet per second): QMXOUT is a one-dimensional array with one term for each river node. The terms are in the same order as in RIVER.

Each of the variables associated with head-dependent flow are defined here as they would be used to represent a stream, a drain, or a spring. Evapotranspiration may be represented by defining the terms as described above in the head-dependent flow section of the user's guide. The default values of all the variables associated with head-dependent flow boundaries are zero.

Variables associated with output are:

VARIABLE	DEFAULT	USE
NCUBES	Conditional	Number of output cubes carried over from a previous run when restarting. When NCUBES is not specified, output cubes in block 9 are added to those carried over when restarting. When NCUBES=0, no output cubes are carried over.
NPCH	10	Number of plot characters used on alphanumeric contour maps. NPCH=20 may be specified.
MØDPR	5	There is output from the model every MØDPR'th time step during each pumping period and at the end of each pumping period. If printout is desired only at the end of each pumping period, set MØDPR to a high value.

The order in which 3D array variables (block 7) are entered in blocks 7 and 9 may be specified (Posson and others, 1980, p. 106). However, the author has found the default values indicated on table 5 adequate.

Table 5. Default values for the LC... variables

NVPN LC.... Variable	13	15	18	20
LCPHI	0	0	0	0
LCWEL	1	1	1	1
LCSTR	2	2	2	2
LCT	3	3	3	3
LCS	4	4	4	4
LCTR	5	5	5	5
LCTC	6	6	6	6
LCTK	7	7	7	7
LCEL	8	8	8	8
LCFL	9	9	9	9
LCGL	10	10	10	10
LCV	11	11	11	11
LCXI	12	12	12	12
LCBOT	-	13	-	13
LCPERM	-	14	-	14
LCTL	-	-	13	15
LCTLK	-	-	14	16
LCSL	-	-	15	17
LCZCB	-	-	16	18
LCRATE	-	-	17	19

Block 4 is terminated with $END starting in any of columns 2-77.

Data input block 5: HEADING

Block 5 has four records:

RECORD	COLUMNS	USE
1	1-6	HEADER
2	1-80	Text to be printed at the top of each page of output.
3	1-52	Text continued.
4	1-3	END

Data input block 6: SYMBOLS

In this block, numeric values are assigned to symbols which will be used in blocks 7, 8, and 9 to initialize or change arrays. These symbols may consist of one, two, or three alphanumeric characters (fig. 2). Symbol values are not retained on the BAKØUT file so they must be redefined if used in blocks 7, 8, or 9 when restarting (RESTRT=.TRUE.). The maximum number of input cards in block 6 is limited by the maximum dimension specified for symbol-value pairs when the program was compiled.

RECORD	COLUMNS	USE
1	1-7	SYMBØLS
2 and following	1-3	A symbol comprised of 1, 2, or 3 alphanumeric characters. The program automatically left justifies them. Thus ƀXƀ=Xƀƀ=ƀƀX, but XXƀ≠XƀX.
	4-10	Not used. These columns must be blank.
	11-18	Value assigned to this symbol. This number may be integer, real or in scientific notation. Leading and trailing blank spaces are read as blanks - not zeros.
Last record	1-3	END

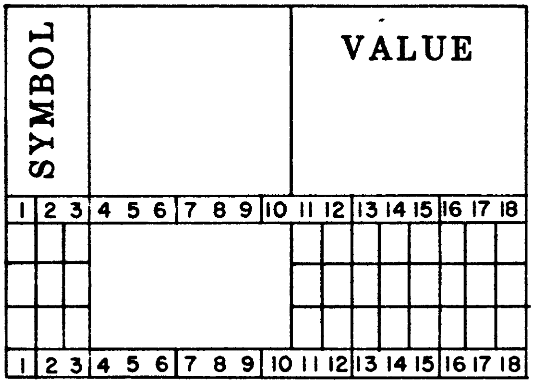

Figure 2. Coding form for input of symbol-value pairs (block 6).

Data input block 7: 3D INPUT

Three-dimensional array variables are those variables that have a value associated with each node of the model. A minimum of 13 variables are used.

PHI	The calculated head (feet) for the present iteration, normally input by the modeler using exact values at constant heads ($S < 0$) and approximate values elsewhere.
WEL	The pumpage term at each node (feet per second), normally calculated by the program from pumpage data (block 12), not normally input by the modeler as 3D INPUT.
STRT	The starting head (feet), normally input by the modeler. The calculated head (PHI) is subtracted from STRT to calculate drawdown.
T	The transmissivity (feet squared per second) if EQN4=.TRUE., or the hydraulic conductivity (feet per second) if EQN3=.TRUE., always input by the modeler. The values TR, TC, and TK (below) are used in calculations of the SIP algorithm. T is used as a flag to indicate whether the node is active ($T \neq 0$) or inactive ($T=0$) and in the initial calculation of TR, TC, and TK. However, on a restart non-zero values are in TR, TC, and TK from the BAKIN file. When the user intends to change the value of T from that used when the BAKIN file was created, TR, TC, and TK should be set to zero. This will allow new values of TR, TC, and TK to be calculated from the new T values.
S	The storage coefficient (dimensionless) if EQN4=.TRUE., or the specific storage (per foot) if EQN3=.TRUE., or a flag indicating a constant head ($S < 0$), always input by the modeler.
TR	The harmonic mean of the transmissivities in the x direction between the jth node and the node at j+1, accounting for the node sizes $DELX_j$ and $DELX_{j+1}$ (Trescott, 1975, equation 26a), normally calculated by the program but may be input by the modeler. The program will calculate TR for each node where TR is not preset by the modeler. On a restart, the earlier TR value is on the BAKIN file. To have TR recalculated from a new T value a zero must be entered for TR.
TC	Similar to TR but in the y direction (Trescott, 1975, equation 26b).
TK	Similar to TR and TC but in the z direction (Trescott and Larson, 1976, equation V).

EL,FL,GL,V, and XI

Intermediate variables calculated and used by the program, not normally input by the modeler.

Two more 3D variables are needed when a water table is to be simulated in any layer below the top layer (WTABLE=.TRUE. and the code is compiled to allow water table conditions in all layers):

BOT	The bottom altitude (feet) of the layer, input by the modeler.
PERM	The horizontal hydraulic conductivity (feet per second) of the saturated portion of the layer, input by the modeler. TK is calculated from the value of T and is not altered while saturated thickness remains positive. For active nodes ($T \neq 0$), T is recalculated as the product of hydraulic conductivity (PERM) and saturated thickness (PHI minus BOT). This T is used for calculating the values of TR and TC used in the calculations of the SIP algorithm.

Five more 3D variables are needed if transient leakage is used (TRLEAK=.TRUE.):

TL,TLK, and SL	Intermediate variables calculated and used by the program, not normally input by the modeler;
ZCB	The thickness (feet) of the overlying confining bed, input by the modeler;
RATE	The vertical hydraulic conductivity (feet per second) of the overlying confining bed, input by the modeler.

The first record of block 7 has 3D INPUT in columns 1-8. Subsequent records have 26 fields of three columns each as in figure 3. Columns 19-20 are not used. Numbers or symbols may be right or left justified or centered in these fields; the program automatically left justifies them.

The first six fields of each record designate the cube (node or block of nodes) to which the data on the remainder of the card applies. The first field contains the number of the first row of this cube and the second contains the number of the last row of this cube. Similarly, fields 3 and 4 contain the numbers of the first and last columns, and fields 5 and 6 contain the numbers of the lowermost and uppermost layers.

NVPN=13

VARIABLE NAME	PHI	WEL	STRT	T	S	TR	TC	TK	EL	FL	GL	V	XI
VARIABLE LOCATION	0	1	2	3	4	5	6	7	8	9	10	11	12

NVPN=15

VARIABLE NAME	PHI	WEL	STRT	T	S	TR	TC	TK	EL	FL	GL	V	XI	BOT	PERM
VARIABLE LOCATION	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14

NVPN=18

VARIABLE NAME	PHI	WEL	STRT	T	S	TR	TC	TK	EL	FL	GL	V	XI	TL	TLK	SL	ZCB	RATE
VARIABLE LOCATION	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17

NVPN=20

VARIABLE NAME	PHI	WEL	STRT	T	S	TR	TC	TK	EL	FL	GL	V	XI	BOT	PERM	TL	TLK	SL	ZCB	RATE
VARIABLE LOCATION	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19

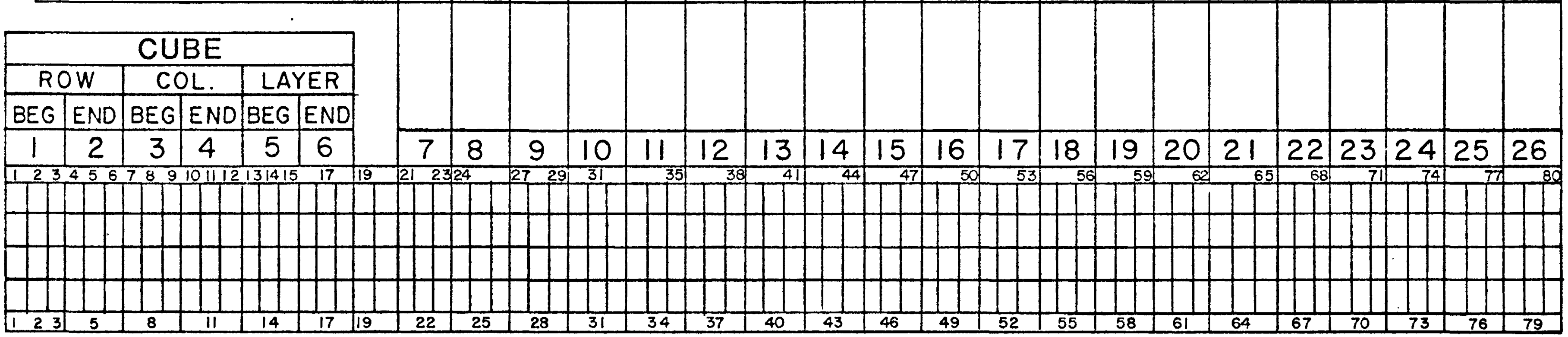

Figure 3. Coding form for input of 3D variables (block 7) showing fields 1-26 and the default locations.

To simplify coding, two conventions are established. First, if only one of the first or second fields is coded, the program will set them both equal and only one row will be affected. Second, if neither of the first or second fields is coded, then the program will place a "1" in the first field and the value of NROW in the second field so that all rows will be affected. Columns are treated similarly in fields 3 and 4, as are layers in fields 5 and 6. Thus, for example, if all of fields 1-6 are left blank, the whole model will be affected by the data coded on the remainder of the card.

Each of the remaining fields 7-26 (columns 21-80) is dedicated to a particular variable following the order specified by the LC.... parameters in block 4. The variable whose location is 0 (LC....=0) has field 7 (columns 21-23) dedicated to it, the variable whose location is 1 (LC....=1) has field 8 (columns 24-26), etc. In figure 3 the order of variables shown is the default order (table 5).

A variable is initialized (for a particular cube) by placing in its field a symbol representing the desired value as specified in block 6. Thus, for example, if the symbol HIA were given the value of 1,000 in block 6 and the default location of the variable STRT were used, then placing HIA in field 9 (columns 27-29) would initialize the starting head at 1,000.

Variables corresponding to fields that are blank are not initialized. For example, a cube with a symbol in the T field, and blanks in all other fields, will initialize only the variable T.

In block 7, the order of the records is very important because values may be overwritten, or changed by subsequent records.

When restarting, values of TR, TC, and TK are not automatically overwritten when the value of T is changed. The program will use a new T value to recalculate the variables TR, TC, and TK for those nodes at which the value is zero. A safe procedure is to set TR, TC, and TK to zero at all nodes for any run in which any value of T is changed. Otherwise, the averaging scheme may carry over values calculated from old T values. For example, if the value of T is changed for row 3, and the value of TR is set to zero for row 3 only, the value of TR for row 2 will not be recalculated. Similarly, spurious values of TC and TK can be introduced.

Constant-head cubes are specified by initializing S to a negative value and both PHI and STRT to the desired head.

The last record in block 7 has END in columns 1-3.

Block 7 may be omitted when there is no 3D input as may be the case when RESTRT=.TRUE.

The total number of input records in blocks 7, 8, and 9 may not exceed either the maximum dimension specified for symbol-value pairs when the program was compiled or NVPL divided by 20. If more input records are required, the restart option can be used to complete the model definition in several steps. By defining T values on the last restart, no calculations are performed until model definition is complete.

Data input block 8: 2D INPUT

Certain variables are in the form of two-dimensional arrays:

QRE	Recharge rate per unit area of land surface (feet per second if EQN4=.TRUE.).
PERM	Horizontal hydraulic conductivity (feet per second). PERM may be a 3D or a 2D variable depending on how the program is compiled. When it is a 2D variable, it is input here and applied only to the top layer.
BOT	Bottom altitude (feet). Like PERM, BOT may be either a 3D or 2D variable. When it is a 2D variable, it is input here and applied only to the top layer.

The first record of block 8 has 2D INPUT is columns 1-8. Subsequent records are divided into 8 fields of three columns each (fig. 4). Fields 1-4 are used exactly as in block 7: to specify the beginning and ending rows and columns respectively of a cube to which data on the remainder of the record applies. Field 5 or 6 should designate the top layer. Otherwise, the variables BOT and PERM will be overwritten as each layer is processed. The practice of designating the top layer on some records and leaving fields 5 and 6 blank on others should be avoided. The records without the layer designation are reprocessed for each layer overwriting the variables defined by records with the layer designation.

Field 7 may contain one of the three keywords PRM, BOT, or QRE. If PRM is in field 7, then an alphanumeric symbol for the value of horizontal hydraulic conductivity of the top layer must be in field 8. (The symbol in field 8 must have been defined in block 6.) Likewise, if BOT is in field 7, then a symbol for the bottom altitude of the uppermost layer must be in field 8; and if QRE is in field 7, then a symbol for the recharge flux must be in field 8.

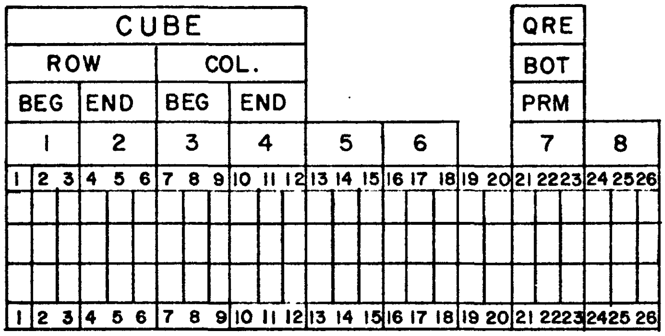

Figure 4. Coding form for input of 2D variables (block 8) showing fields 1-8 and permissible keywords.

The last record in block 8 has END in columns 1-3.

If there is no 2D input, block 8 may be omitted.

The total number of input records in blocks 7, 8, and 9 may not exceed either the maximum dimension specified for symbol-value pairs when the program was compiled or NVPL divided by 20. If more input records are required refer to the paragraph at the end of block 7.

Data input block 9: OUTPUT CUBES

Output from the model is controlled in block 9. Output may be in the form of printed lists, maps, and hydrographs. Values for any or all 3D variables in any or all nodes may be output.

The first record of block 9 has OUTPUT CUBES in columns 1-12.

Subsequent records are divided into 13 fields of three columns each (fig. 5). The first 6 fields are used to specify the cube for which output is desired as in blocks 7 and 8 above. Fields 7 through 13 may contain the combinations of keywords, numbers, and symbols shown in table 6.

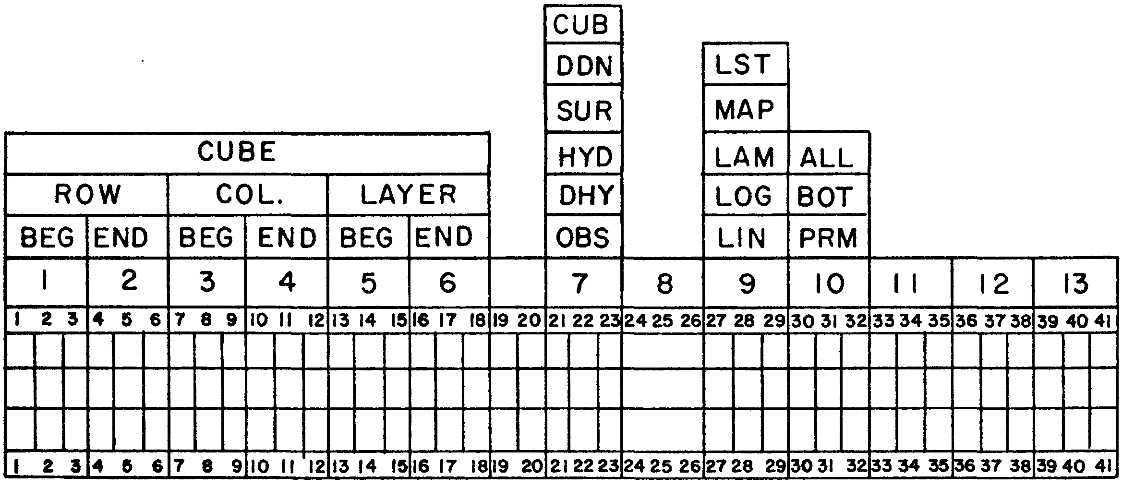

Figure 5. Coding form for specifying output (block 9) showing fields 1-13 and permissible keywords.

Table 6. Acceptable combinations of keywords, numbers, and symbols for OUTPUT CUBES

FIELD 7	FIELD 8	FIELD 9	FIELD 10	FIELD 11	FIELD 12	FIELD 13
CUB	Symbol for the desired variable	LST	-	-	-	-
CUB	-	LST	ALL or BOT or PRM	-	-	-
CUB	Symbol for the desired variable	MAP or LAM	Symbol for map scale X.(feet per inch)	Symbol for map scale Y.(feet per inch)	Symbol for contour interval (feet)	Symbol for base elevation (feet)
DDN or SUR	-	LST	-	-	-	-
DDN or SUR	-	MAP or LAM	Symbol for map scale X.(feet per inch)	Symbol for map scale Y.(feet per inch)	Symbol for contour interval (feet)	Symbol for base elevation (feet)
HYD or DHY	Symbol for vertical scale (feet per inch)	L0G	Symbol for horizontal scale (inches per log cycle)	-	-	-
HYD or DHY	Symbol for vertical scale (feet per inch)	LIN	Symbol for horizontal scale (seconds per inch)	-	-	-
0BS	-	-	-	-	-	-

The values of "symbols" must be defined in block 6. Note that the "symbol for the desired variable" must correspond to an integer from 0-19 corresponding to the LC.... variables in block 4 (defaults in table 5).

The keywords that may appear in field 7 are defined as:

CUB	One or all of the 3D array variables will be indicated on field 8 or 10.
DDN	Drawdown (STRT minus PHI).
SUR	The unconfined water surface; i.e., the heads in the topmost active nodes.
HYD	A "hydrograph" of head at the end of each time step for the first node of the cube.
DHY	A "hydrograph" of drawdown (STRT minus PHI) at the end of each time step for the first node of the cube.
0BS	A "hydrograph" of observed head or drawdown will be plotted on the same axes as the HYD or DHY hydrograph for the first node of the cube.

The keywords that may appear in field 9 are defined as:

LST	A printed list of the array values.
MAP	A printed map of the array values.
LAM	Both a list and a map of the array values.
L0G	The horizontal (time) scale of the hydrograph is logarithmic.
LIN	The horizontal (time) scale of the hydrograph is linear.

The keywords that may appear in field 10 are defined as:

ALL	List of all of the 3D array variables.
B0T	List of the 2D array for the bottom elevation of the top layer.
PRM	List of the 2D array for the horizontal hydraulic conductivity of the top layer.

Special techniques are required to obtain maps of certain variables because the META routine uses only positive integers. For the sole purpose of mapping parameters that are normally less than 1 such as T and S, the appropriate symbols in block 6 may be defined to positive integer values and the model run for one iteration with DAMP = 0. Array values that may be negative, such as drawdown, can be mapped by specifying a negative base elevation in field 13.

When the size and scale of a map are such that more than one 10 x 12 inch map segment (printer page) is required and a plot character spans the boundary of the map segment, an error message "(X,Y) OUT OF BOUNDS" will appear. This may require no action on the part of the user.

If a map or hydrograph is defined (keywords HYD, DHY, MAP, or LAM are used in input block 9), then the appropriate records must be included for program execution (block 1).

The last record of block 9 has END in columns 1-3. If no change in output is sought when restarting (RESTRT=.TRUE.), omit block 9. If different output is desired when restarting, set NCUBES=0 (block 4) and specify the output cubes that are desired.

The total number of input records in blocks 7, 8, and 9 may not exceed either the maximum dimension specified for symbol-value pairs when the program was compiled or NVPL divided by 20. If more input records are required, refer to the paragraph at the end of block 7.

Data input block 10: ENDOFCUBES

The cube input is terminated with a record having ENDOFCUBES in columns 1-10. This record is necessary whether or not blocks 5-9 are present.

Data input block 11: NAMELIST $NEWPP

Block 11 is a NAMELIST containing the time specifications and multiplying factors for a pumping period. It is repeated for each successive pumping period.

Block 11 may consist of one or several records. The first record has $NEWPP starting in column 2. Values may be specified for the following variable names:

KP Number of this pumping period. The simulation stops upon finishing the pumping period where KP is greater than or equal to NPER (block 4).

When KP=1, a new simulation is assumed; counters are reset to zero and any well data on the BAKIN file will not be processed; well data (block 12) entered for this pumping period are the only well data processed.

When KP 1, a continuation of the previous simulation is assumed; counters are not reset and any well data on the BAKIN file will be processed; well data (block 12) entered for this pumping period are accumulated with any well data on the BAKIN file.

NWELL Number of wells. NWEL=0 specifies that no wells will be input for this pumping period. Otherwise this variable is omitted. (The modeler may prefer always to use the flag (ROW=0) described in block 12.)

TMAX Maximum time. TMAX is in days.

NUMT Maximum number of time steps.

CDLT Multiplying factor for DELT. The length of each subsequent time step is greater than the previous one by a factor of CDLT. CDLT greater than 1.5 may not be satisfactory.

DELT (Initial time step divided by CDLT.) DELT is in hours.

QFAC Discharge multiplying factors. All, some, or none of the QFAC values may be respecified each pumping period. Those not reset remain at the previous value; they are not set to zero.

After these variables have been specified the NAMELIST is terminated with $END starting in any of the columns 2-77.

To simulate a pumping period of an exact length set NUMT to a larger value than would be necessary with the given DELT and CDLT. The program will calculate a DELT less than or equal to the value coded so that the last time step will arrive at exactly TMAX.

To simulate a certain number of time steps, set TMAX larger than needed and NUMT, CDLT, and DELT will be used exactly as coded.

To simulate both a pumping period of an exact length and a certain number of time steps, the modeler must calculate values of TMAX, NUMT, CDLT, and DELT to arrive at exactly TMAX after NUMT time steps.

Data input block 12: NAMELIST $NEWELL

Block 12 is a NAMELIST containing specifications for well discharge or recharge on a node-by-node basis. It is repeated for each well. Multiple wells may be specified for a single node, in which case the program will automatically accumulate them.

Block 12 may consist of one or several records. The first record has $NEWELL starting in column 2. The following variable names may be defined:

RØW	The row of the well node.
CØL	The column of the well node.
LAYER	The layer of the well node.

Any RØW, CØL, or LAYER specified as 0 indicates that the last well for the pumping period has been input.

Q	Pumping rate. The units of Q may be feet cubed per second if EQN4=.TRUE. or feet squared per second if EQN3=.TRUE. However, the use of QTYPE (below) and QFAC (blocks 4 and 11) allows Q to be input in any convenient units. The pumping rate (Q times QFAC) is negative for discharge and positive for recharge.
QTYPE	Subscript for the one-dimensional array of multiplying factors (QFAC). QTYPE=1 means that the first term of QFAC (blocks 4 and 11) will be used to convert Q to the correct units. QTYPE=2 means that the second term of QFAC will be used. The default value of QTYPE is 100 and the default value of QFAC(100) is 1. Thus, if QTYPE is not specified the program assumes that Q is being input in consistent units.

The Q and QTYPE associated with each specified-flow boundary are retained in memory throughout the simulation. At the beginning of each pumping period, the rate of withdrawal is recalculated as the product of Q and QFAC(QTYPE). Once entered, a well may be turned off (that is, the flow may be specified as zero) by defining the appropriate QFAC as zero.

The number of wells defined in block 12 is limited by the maximum number of active wells defined when the program was compiled.

The NAMELIST is terminated with $END beginning in columns 2-77.

Data input block 13: NAMELIST $NEWRIV

Block 13 is a NAMELIST that allows the modeler to respecify head-dependent flow boundaries at each new pumping period.

Block 13 may consist of one or several records. The first record has $NEWRIV starting in column 2. The value associated with the following variable names may be defined:

NR	Number of river reaches.
NRC	Number of nodes in each river reach.
RQ	Flow (cubic feet per second) into each river reach from outside the model.
NADD	The destination for outflow from each river reach.
RIVER	Elevation (feet) of the river at each river node.
VK	Leakance coefficient (per second) for each river node.
QMAX	Maximum infiltration rate (cubic feet per second) for each river node.
QMXOUT	Maximum rate (cubic feet per second) of flow from ground water for each river node.

The variables are discussed more fully in block 4.

The NAMELIST is terminated with $END beginning in columns 2-77.

A typical way that blocks 11, 12, and 13 are entered is to code the time specifications, one pumping period to a record, and the well data, one well to a record, and sequence them along with the river data as follows:

```
$NEWPP KP=1..........$END        First pumping period of this run.

$NEWELL..............$END        Wells associated with this pumping
    .                              period.  (There may be none.)

$NEWELL RØW=0,.......$END        Flag.

$NEWRIV..............$END        River data.

$NEWPP KP=2..........$END        Second pumping period.

$NEWELL..............$END        Wells.
    .
    .
    .
$NEWELL RØW=0,.......$END        Flag.

$NEWRIV..............$END        River data.
    .
    .
    .
    .
$NEWPP KP=XXX,.......$END        Where XXX=NPER, indicating that this
                                   is the last pumping period.

$NEWELL..............$END        Wells.
    .
    .
    .
$NEWELL RØW=0,.......$END        Flag.

$NEWRIV..............$END        River data.
```

SAMPLE SIMULATION

This section presents the input and output for a sample simulation. The sample involves two stages, a steady-state simulation and a transient simulation. The transient simulation uses the steady-state condition as the initial stable condition.

Steady-state simulation

The job stream used to simulate the steady-state condition is shown in table 7. The job stream initiates two jobs, one on CDC and one on the CRAY-1. The CDC job copies input data to permanent files and initiates the CRAY-1 job which accesses the permanent files. Output from the CDC job is a dayfile not shown here. Output from the CRAY-1 job follows table 7.

Table 7. Job stream used for steady-state simulation with multiple "rivers" defined for some nodes

```
WRUH1CRAJCL,T177,IO177,ST066.
ACCOUNT,********************************.
COMMENT.     COPY DATA TO A PERMANENT FILE ON CDC           ***************
REQUEST,DATA,*PF.
COPYBR,INPUT,DATA.
PURGE,OLDDATA,CRADATAGLENN,ID=USGSPOS,NA=1,LC=1.
RETURN,OLDDATA.
CATALOG,DATA,CRADATAGLENN,ID=USGSPOS.
COMMENT.     COPY CRAY CONTROL DECK TO A PERMANENT FILE ON CDC     ********
REQUEST,INCRA,*PF.
COPYBR,INPUT,INCRA.
PURGE,OLDRUN,CRAJCLGLENN,ID=USGSPOS,NA=1,LC=1.
RETURN,OLDRUN.
CATALOG,INCRA,CRAJCLGLENN,ID=USGSPOS.
COMMENT.     ZAP FILE TO CRAY FOR EXECUTION                      *************
ZAP,INCRA,F9,,IN.
$EOR
 $CONTROL
 PHISET=.TRUE.,
 SELRES=.TRUE.,
 $END
BAKIN                BAKOUT
 $INLIST
 NVPN=15,
 NROW=20,
 NCOL=20,
 NLAYER=2,
 WTABLE=T,
 NPER=1,
 MODPR=100,
 NRHOP=5,
 ITMAX=400,
 CLSURE=0.0001,
 DELX=20*1000,
 DELY=20*1000,
 DELZ=2*100,
 FACTX=2*1.0,
 FACTY=2*1.0,
 FACTZ=2*.1E-6,
 EQN4=.TRUE.,
 SY(2)=0.0,
 NR=5,
 NRC=10,6,7,6,5,
 NADD=3,3,0,5,
 QMAX=23*1.0,11*0.0,
 QMXOUT=23*1.0,11*1.0,
 RIVER=185,  180,  175,  170,  165,  160,  155,  150,  145,  140,
       158,  156,  154,  150,  145,  140,
       135,  130,  125,  120,  115,  110,  105,
       130,  125,  120,  130,  125,  120,
       115,  110,  105,   95,   90,
 INDX= 8,19,  9,18, 10,17, 11,16, 12,15, 12,14, 12,13, 13,12, 13,11, 13,10,
      19,12, 18,12, 17,12, 16,12, 15,11, 14,10,
      13, 9, 13, 8, 13, 7, 12, 6, 12, 5, 11, 4, 11, 3,
      13,12, 13,11, 13,10, 14,12, 14,11, 14,10,
      13, 9, 13, 8, 13, 7, 11, 4, 11, 3,
 VK=23*1.0E-08,11*1.9026E-08,
 RO=3.0,2.0,0,0,0.
 $END
```

Table 7. Job stream used for steady-state simulation with multiple "rivers" defined for some nodes - Continued

```
HEADER
 * * * * EXAMPLE FOR APPENDIX  * * * * TWO-AQUIFER PROBLEM WITH HEAD-DEPENDENT
AND SPECIFIED HEAD BOUNDARIES ****
END
SYMBOLS
ZIP       0
H02       100
H03       105
H04       110
H05       115
H06       120
H07       125
H08       130
H09       135
H10       140
H11       145
H12       150
H13       155
H14       160
H15       165
H16       170
H17       175
H18       180
H19       185
TI        0.1
SO        0.0
BT2       90
K         0.001
CH        -1.0
TK        1.0E-8
END
3D INPUT
          2         H02
          3         H03
          4         H04
          5         H05
          6         H06
          7         H07
          8         H08
          9         H09
         10         H10
         11         H11
         12         H12
         13         H13
         14         H14
         15         H15
         16         H16
         17         H17
         18         H18
         19         H19
              1  2           TI SO
           2     2  H02          CH
                 2                                           KBT2
END
OUTPUT CUBES
              1  2  CUBZIPLST
END
ENDOFCUBES
```

Table 7. Job stream used for steady-state simulation with multiple "rivers" defined for some nodes - Concluded

```
 $NEWPP KP=1, NWEL=0, TMAX=1, NUMT=1, CDLT=1.0, DELT=24, $END
 $NEWRIV  $END
$EOR
WRUH2CRAJCL,T177,IO10,STCRA.
ACCOUNT,******************************.
JOB,T=177.
*.     ACQUIRE THE EXECUTABLE BINARIES                   ***************
ACQUIRE,DN=BLD,PDN=CRA2020FD3D,ID=USGSPOS,DF=TR,UQ.
DELETE,DN=BLD.
RELEASE,DN=$IN.
*.     ACQUIRE THE DATA DECK                             ***************
ACQUIRE,DN=FT05,PDN=CRADATAGLENN,ID=USGSPOS,UQ.
DELETE,DN=FT05.
*.     SET UP FILE FOR TRANSIENT LEAKAGE - IF TRLEAK=.T.    **************
*.ASSIGN,DN=LTRFIL,A=FT41,RDM,BS=44.
*.WRITEDS,DN=LTRFIL,NR=2,RL=1620.
*.     WHERE NR=2X(NLAYER-1)     2X(2-1)=2
*.     RL=MODE X NROW X NCOL     5X18X18=1620.
*.     ACQUIRE THE BAKIN FILE - IF RESTRT=.T.            ***************
*.ACQUIRE,DN=FT03,PDN=NEWABAKOUT,ID=USGSPOS,DF=TR,UQ.
*.ASSIGN,DN=FT03,A=BAKIN.
*.DELETE,DN=FT03.
*.     LOAD EXECUTABLE CODE AND EXECUTE ON DATA         ***************
LDR,LIB=METALIB,SET=ZERO,DN=BLD.
*.     ROUTE THE META FILE OUT TO TERMINAL - IF META OUTPUT *************
ACCESS,DN=DIRECT.
DIRECT,I=FT99,DEV=PRINTER.
*.     CATALOG BAKOUT AS A PERMANENT FILE ON CDC - IF SELRES=.T.***********
REWIND,DN=FT04.
DISPOSE,DN=FT04,SDN=NEWABAKOUT,ID=USGSPOS,DC=ST,RT=999,WAIT,DF=TR.
AUDIT,ID=USGSPOS.
EXIT.
$EOF
```

Output from the CRAY-1 is grouped for discussion into initial values, pumping period, and dayfile. Initial values are those defined in input blocks 2-10. Input blocks 2 and 4 are listed in NAMELIST format. Variables used to define head-dependent flow boundaries (block 4) are repeated in easier-to-read tabular form. The heading (block 5) is followed by a list of records of data input blocks 6-9. Simple format errors (such as using a symbol which was not defined) would have been noted here and caused program termination. Finding no format errors, the data initialization commands are listed as they are executed. Additional output includes grid spacing, transmissivity multipliers, and a list of nodes which are initially in a water-table condition (PHI is not greater that BOT plus DELZ). Dry nodes (PHI is not greater that BOT) would also be indicated here. A list of iteration parameters terminates the listing of initial values.

Output generated by the first (and in this case only) pumping period follows the list of iteration parameters. Variables defined in input blocks 11-13 are listed in tabular and NAMELIST format. In this case, there are no wells (block 12) and the river data (block 13) are not changed from the values defined in data input block 4.

After the simulation of the pumping period in 1 time step of 47 iterations, the final values of PHI are listed for both layers as requested in table 7. The mass balance, specified-head flow, and flow between layers is followed by a summary of the head-dependent flow boundaries. The layer will be specified as zero if either (1) the rate to ground water has been zero for every iteration (as for river nodes 21, 27, and 28) or (2) the same row and column has been defined as a lower numbered river node (as for river nodes 24, 25, 26, 29, 30, 31, 32, 33, and 34). Since no flow reaches the downstream end of reach 1, only the discharge from reach 2 (0.5007 cubic foot per second) is routed to the upstream end of reach 3. After losing 0.1695 cubic foot per second to ground water in row 13, column 9, layer 2, 0.3312 cubic foot per second are routed downstream to row 13, column 8, layer 2. Tables of maximum head change per iteration and iterations per time step conclude the output for the only pumping period.

The dayfile should be checked to verify that the appropriate files have been attached and cataloged. The executable binaries were from cycle 2 of CRA2020FD3D; the input data were from cycle 1 of CRADATAGLENN; the BAKOUT file was cataloged as cycle 1 of NEWABAKOUT (40,512 words). Abnormal terminations would also be noted in the dayfile.

```
&CONTROL  RESTRT = .F.,  RSRTPP = .F.,  RSRTTS = .F.,  RSRTIT = .F.,  SELRES = .T.,  RECMPL = .F.,  USELCM = .T.,  USEBIO = .F.,
 USERMS = .F.,  PHISET = .T.,  PHIDMP = .F.,  WELZRO = .T.,  DMPINT = .F.,  ONLYIN = .F.,  TRACE = .F.,  MF7000 = .T.,
 MF6000 = .F.,  DMPIT = .F.,  DMPTS = .F.,  DMPPP = .F.,  DMPVAR = .F.,  ZRMBAL = .F.,  DMPRIV = .F.,  &END
&INLIST  NVPN = 15,  NROW = 20,  NCOL = 20,  NLAYER = 2,  NNPL = 400,  NNAL = 800,  NWPL = 6000,  NWAL = 12000,  LCPHI = 0,
 LCWEL = 1,  LCSTR = 2,  LCT = 3,  LCS = 4,  LCTR = 5,  LCTC = 6,  LCTK = 7,  LCEL = 8,  LCFL = 9,  LCGL = 10,  LCV = 11,
 LCXI = 12,  LCBOT = 13,  LCPERM = 14,  LCTL = 0,  LCTLK = 0,  LCSL = 0,  LCZCB = 0,  LCRATE = 0,  MBALPR = .T.,  DAMP = 1.,
 MODE = 0,  MODPR = 100,  WTABLE = .T.,  TRLEAK = .F.,  RCHRG = .F.,  EQN3 = .F.,  EQN4 = .T.,  NPER = 1,  CLSURE = 1.E-4,
 NRHOP = 5,  WMAX = 0.,  RHOP = 20*0.,  ITMAX = 400,  NPCH = 10,  QFAC = 100*1.,  DELX = 20*1000.,  130*0.,  DELY = 20*1000.,
 130*0.,  DELZ = 2*100.,  148*0.,  FACTX = 2*1.,  148*0.,  FACTY = 2*1.,  148*0.,  FACTZ = 2*1.E-7,  148*0.,  SS = 150*0.,
 SY = 150*0.,  NCUBES = 0,  NR = 5,  NRC = 10,  6,  7,  6,  5,  5*0,  NADD = 2*3,  0,  5,  6*0,  QMAX = 23*1.,  77*0.,
 RIVER = 185.,  180.,  175.,  170.,  165.,  160.,  155.,  150.,  145.,  140.,  158.,  156.,  154.,  150.,  145.,  140.,  135.,
 130.,  125.,  120.,  115.,  110.,  105.,  130.,  125.,  120.,  130.,  125.,  120.,  115.,  110.,  105.,  95.,  90.,  66*0.,
 VK = 23*1.E-8,  11*1.9026E-8,  66*0.,  RQ = 3.,  2.,  8*0.,  INDX = 8,  19,  9,  18,  10,  17,  11,  16,  12,  15,  12,  14,
 12,  2*13,  12,  13,  11,  13,  10,  19,  12,  18,  12,  17,  12,  16,  12,  15,  11,  14,  10,  13,  9,  13,  8,  13,  7,  12,
 6,  12,  5,  11,  4,  11,  3,  13,  12,  13,  11,  13,  10,  14,  12,  14,  11,  14,  10,  13,  9,  13,  8,  13,  7,  11,  4,
 11,  3,  132*0,  QMXOUT = 34*1.,  66*0.,  &END
```

copy of
[illegible]

```
RIVER    1 NUMB.REACH NODES=>  10 ADD DISCHARGE TO REACH=>   3 RQ DISCHARGE=> 0.30000E+01

          NODE   1 ROW=>   8 COL=>  19 STREAMBED ELEV=> 0.18500E+03 VERT. COND.=> 0.10000E-07 MAX.INFILT. RATE=> 0.10000E+01
          NODE   2 ROW=>   9 COL=>  18 STREAMBED ELEV=> 0.18000E+03 VERT. COND.=> 0.10000E-07 MAX.INFILT. RATE=> 0.10000E+01
          NODE   3 ROW=>  10 COL=>  17 STREAMBED ELEV=> 0.17500E+03 VERT. COND.=> 0.10000E-07 MAX.INFILT. RATE=> 0.10000E+01
          NODE   4 ROW=>  11 COL=>  16 STREAMBED ELEV=> 0.17000E+03 VERT. COND.=> 0.10000E-07 MAX.INFILT. RATE=> 0.10000E+01
          NODE   5 ROW=>  12 COL=>  15 STREAMBED ELEV=> 0.16500E+03 VERT. COND.=> 0.10000E-07 MAX.INFILT. RATE=> 0.10000E+01
          NODE   6 ROW=>  12 COL=>  14 STREAMBED ELEV=> 0.16000E+03 VERT. COND.=> 0.10000E-07 MAX.INFILT. RATE=> 0.10000E+01
          NODE   7 ROW=>  12 COL=>  13 STREAMBED ELEV=> 0.15500E+03 VERT. COND.=> 0.10000E-07 MAX.INFILT. RATE=> 0.10000E+01
          NODE   8 ROW=>  13 COL=>  12 STREAMBED ELEV=> 0.15000E+03 VERT. COND.=> 0.10000E-07 MAX.INFILT. RATE=> 0.10000E+01
          NODE   9 ROW=>  13 COL=>  11 STREAMBED ELEV=> 0.14500E+03 VERT. COND.=> 0.10000E-07 MAX.INFILT. RATE=> 0.10000E+01
          NODE  10 ROW=>  13 COL=>  10 STREAMBED ELEV=> 0.14000E+03 VERT. COND.=> 0.10000E-07 MAX.INFILT. RATE=> 0.10000E+01

RIVER    2 NUMB.REACH NODES=>   6 ADD DISCHARGE TO REACH=>   3 RQ DISCHARGE=> 0.20000E+01

          NODE   1 ROW=>  19 COL=>  12 STREAMBED ELEV=> 0.15800E+03 VERT. COND.=> 0.10000E-07 MAX.INFILT. RATE=> 0.10000E+01
          NODE   2 ROW=>  18 COL=>  12 STREAMBED ELEV=> 0.15600E+03 VERT. COND.=> 0.10000E-07 MAX.INFILT. RATE=> 0.10000E+01
          NODE   3 ROW=>  17 COL=>  12 STREAMBED ELEV=> 0.15400E+03 VERT. COND.=> 0.10000E-07 MAX.INFILT. RATE=> 0.10000E+01
          NODE   4 ROW=>  16 COL=>  12 STREAMBED ELEV=> 0.15000E+03 VERT. COND.=> 0.10000E-07 MAX.INFILT. RATE=> 0.10000E+01
          NODE   5 ROW=>  15 COL=>  11 STREAMBED ELEV=> 0.14500E+03 VERT. COND.=> 0.10000E-07 MAX.INFILT. RATE=> 0.10000E+01
          NODE   6 ROW=>  14 COL=>  10 STREAMBED ELEV=> 0.14000E+03 VERT. COND.=> 0.10000E-07 MAX.INFILT. RATE=> 0.10000E+01

RIVER    3 NUMB.REACH NODES=>   7 ADD DISCHARGE TO REACH=>   0 RQ DISCHARGE=> 0.00000E+00

          NODE   1 ROW=>  13 COL=>   9 STREAMBED ELEV=> 0.13500E+03 VERT. COND.=> 0.10000E-07 MAX.INFILT. RATE=> 0.10000E+01
          NODE   2 ROW=>  13 COL=>   8 STREAMBED ELEV=> 0.13000E+03 VERT. COND.=> 0.10000E-07 MAX.INFILT. RATE=> 0.10000E+01
          NODE   3 ROW=>  13 COL=>   7 STREAMBED ELEV=> 0.12500E+03 VERT. COND.=> 0.10000E-07 MAX.INFILT. RATE=> 0.10000E+01
          NODE   4 ROW=>  12 COL=>   6 STREAMBED ELEV=> 0.12000E+03 VERT. COND.=> 0.10000E-07 MAX.INFILT. RATE=> 0.10000E+01
          NODE   5 ROW=>  12 COL=>   5 STREAMBED ELEV=> 0.11500E+03 VERT. COND.=> 0.10000E-07 MAX.INFILT. RATE=> 0.10000E+01
          NODE   6 ROW=>  11 COL=>   4 STREAMBED ELEV=> 0.11000E+03 VERT. COND.=> 0.10000E-07 MAX.INFILT. RATE=> 0.10000E+01
          NODE   7 ROW=>  11 COL=>   3 STREAMBED ELEV=> 0.10500E+03 VERT. COND.=> 0.10000E-07 MAX.INFILT. RATE=> 0.10000E+01

RIVER    4 NUMB.REACH NODES=>   6 ADD DISCHARGE TO REACH=>   5 RQ DISCHARGE=> 0.00000E+00

          NODE   1 ROW=>  13 COL=>  12 STREAMBED ELEV=> 0.13000E+03 VERT. COND.=> 0.19026E-07 MAX.INFILT. RATE=> 0.00000E+00
          NODE   2 ROW=>  13 COL=>  11 STREAMBED ELEV=> 0.12500E+03 VERT. COND.=> 0.19026E-07 MAX.INFILT. RATE=> 0.00000E+00
          NODE   3 ROW=>  13 COL=>  10 STREAMBED ELEV=> 0.12000E+03 VERT. COND.=> 0.19026E-07 MAX.INFILT. RATE=> 0.00000E+00
          NODE   4 ROW=>  14 COL=>  12 STREAMBED ELEV=> 0.13000E+03 VERT. COND.=> 0.19026E-07 MAX.INFILT. RATE=> 0.00000E+00
          NODE   5 ROW=>  14 COL=>  11 STREAMBED ELEV=> 0.12500E+03 VERT. COND.=> 0.19026E-07 MAX.INFILT. RATE=> 0.00000E+00
          NODE   6 ROW=>  14 COL=>  10 STREAMBED ELEV=> 0.12000E+03 VERT. COND.=> 0.19026E-07 MAX.INFILT. RATE=> 0.00000E+00

RIVER    5 NUMB.REACH NODES=>   5 ADD DISCHARGE TO REACH=>   0 RQ DISCHARGE=> 0.00000E+00

          NODE   1 ROW=>  13 COL=>   9 STREAMBED ELEV=> 0.11500E+03 VERT. COND.=> 0.19026E-07 MAX.INFILT. RATE=> 0.00000E+00
          NODE   2 ROW=>  13 COL=>   8 STREAMBED ELEV=> 0.11000E+03 VERT. COND.=> 0.19026E-07 MAX.INFILT. RATE=> 0.00000E+00
          NODE   3 ROW=>  13 COL=>   7 STREAMBED ELEV=> 0.10500E+03 VERT. COND.=> 0.19026E-07 MAX.INFILT. RATE=> 0.00000E+00
          NODE   4 ROW=>  11 COL=>   4 STREAMBED ELEV=> 0.95000E+02 VERT. COND.=> 0.19026E-07 MAX.INFILT. RATE=> 0.00000E+00
          NODE   5 ROW=>  11 COL=>   3 STREAMBED ELEV=> 0.90000E+02 VERT. COND.=> 0.19026E-07 MAX.INFILT. RATE=> 0.00000E+00
```

```
 * * * * EXAMPLE FOR APPENDIX  * * * * TWO-AQUIFER PROBLEM WITH HEAD-DEPENDENT  AND SPECIFIED HEAD BOUNDARIES ****

  200 SYMBOL-VALUE PAIRS PERMITTED IN THIS SIMULATION.


SYMBOL-VALUE PAIRS DEFINED FOR THIS RUN:

SYMBOL   VALUE
------   ------------
ZIP        0.00000E+00
H02        0.10000E+03
H03        0.10500E+03
H04        0.11000E+03
H05        0.11500E+03
H06        0.12000E+03
H07        0.12500E+03
H08        0.13000E+03
H09        0.13500E+03
H10        0.14000E+03
H11        0.14500E+03
H12        0.15000E+03
H13        0.15500E+03
H14        0.16000E+03
H15        0.16500E+03
H16        0.17000E+03
H17        0.17500E+03
H18        0.18000E+03
H19        0.18500E+03
TI         0.10000E+00
SO         0.00000E+00
BT2        0.90000E+02
K          0.10000E-02
CH        -0.10000E+01
TK         0.10000E-07


  200 INPUT CUBE CARDS PERMITTED IN THIS SIMULATION.


                            1         2         3         4         5         6         7         8
                   12345678901234567890123456789012345678901234567890123456789012345678901234567890

    1 INPUT CARD: (          2         H02                                                         )
    2 INPUT CARD: (          3         H03                                                         )
    3 INPUT CARD: (          4         H04                                                         )
    4 INPUT CARD: (          5         H05                                                         )
    5 INPUT CARD: (          6         H06                                                         )
    6 INPUT CARD: (          7         H07                                                         )
    7 INPUT CARD: (          8         H08                                                         )
    8 INPUT CARD: (          9         H09                                                         )
    9 INPUT CARD: (         10         H10                                                         )
   10 INPUT CARD: (         11         H11                                                         )
   11 INPUT CARD: (         12         H12                                                         )
   12 INPUT CARD: (         13         H13                                                         )
   13 INPUT CARD: (         14         H14                                                         )
   14 INPUT CARD: (         15         H15                                                         )
   15 INPUT CARD: (         16         H16                                                         )
   16 INPUT CARD: (         17         H17                                                         )
   17 INPUT CARD: (         18         H18                                                         )
   18 INPUT CARD: (         19         H19                                                         )
   19 INPUT CARD: (              1  2           TI SO                                              )
   20 INPUT CARD: (           2     2  H02          CH                                             )
   21 INPUT CARD: (                 2                                           KBT2               )
 END OF 3D INPUTBLOCK

   22 INPUT CARD: (              1  2  CUBZIPLST                                                   )
 END OF OUTPUT CUBES INPUT BLOCK
```

```
22 DATA INITIALIZATION COMMANDS

ROW  ROW   COL  COL   LAY  LAY   1-PHI      2-WELL     3-STRT     4-T        5-S        6-TR       7-TC       8-TK       9-EL       10-FL
BEG--END   BEG--END   BEG--END   11-GL      12-V       13-XI      14-BOTTOM  15-PERM

 1 - 20     2 -  2     1 -  2    0.10E+03   NULL       NULL       NULL       NULL       NULL       NULL       NULL       NULL       NULL
                                  NULL      NULL       NULL       NULL       NULL

 1 - 20     3 -  3     1 -  2    0.10E+03   NULL       NULL       NULL       NULL       NULL       NULL       NULL       NULL       NULL
                                  NULL      NULL       NULL       NULL       NULL

 1 - 20     4 -  4     1 -  2    0.11E+03   NULL       NULL       NULL       NULL       NULL       NULL       NULL       NULL       NULL
                                  NULL      NULL       NULL       NULL       NULL

 1 - 20     5 -  5     1 -  2    0.11E+03   NULL       NULL       NULL       NULL       NULL       NULL       NULL       NULL       NULL
                                  NULL      NULL       NULL       NULL       NULL

 1 - 20     6 -  6     1 -  2    0.12E+03   NULL       NULL       NULL       NULL       NULL       NULL       NULL       NULL       NULL
                                  NULL      NULL       NULL       NULL       NULL

 1 - 20     7 -  7     1 -  2    0.12E+03   NULL       NULL       NULL       NULL       NULL       NULL       NULL       NULL       NULL
                                  NULL      NULL       NULL       NULL       NULL

 1 - 20     8 -  8     1 -  2    0.13E+03   NULL       NULL       NULL       NULL       NULL       NULL       NULL       NULL       NULL
                                  NULL      NULL       NULL       NULL       NULL

 1 - 20     9 -  9     1 -  2    0.13E+03   NULL       NULL       NULL       NULL       NULL       NULL       NULL       NULL       NULL
                                  NULL      NULL       NULL       NULL       NULL

 1 - 20    10 - 10     1 -  2    0.14E+03   NULL       NULL       NULL       NULL       NULL       NULL       NULL       NULL       NULL
                                  NULL      NULL       NULL       NULL       NULL

 1 - 20    11 - 11     1 -  2    0.15E+03   NULL       NULL       NULL       NULL       NULL       NULL       NULL       NULL       NULL
                                  NULL      NULL       NULL       NULL       NULL

 1 - 20    12 - 12     1 -  2    0.15E+03   NULL       NULL       NULL       NULL       NULL       NULL       NULL       NULL       NULL
                                  NULL      NULL       NULL       NULL       NULL

 1 - 20    13 - 13     1 -  2    0.15E+03   NULL       NULL       NULL       NULL       NULL       NULL       NULL       NULL       NULL
                                  NULL      NULL       NULL       NULL       NULL

 1 - 20    14 - 14     1 -  2    0.16E+03   NULL       NULL       NULL       NULL       NULL       NULL       NULL       NULL       NULL
                                  NULL      NULL       NULL       NULL       NULL

 1 - 20    15 - 15     1 -  2    0.16E+03   NULL       NULL       NULL       NULL       NULL       NULL       NULL       NULL       NULL
                                  NULL      NULL       NULL       NULL       NULL

 1 - 20    16 - 16     1 -  2    0.17E+03   NULL       NULL       NULL       NULL       NULL       NULL       NULL       NULL       NULL
                                  NULL      NULL       NULL       NULL       NULL

 1 - 20    17 - 17     1 -  2    0.17E+03   NULL       NULL       NULL       NULL       NULL       NULL       NULL       NULL       NULL
                                  NULL      NULL       NULL       NULL       NULL

 1 - 20    18 - 18     1 -  2    0.18E+03   NULL       NULL       NULL       NULL       NULL       NULL       NULL       NULL       NULL
                                  NULL      NULL       NULL       NULL       NULL

 1 - 20    19 - 19     1 -  2    0.18E+03   NULL       NULL       NULL       NULL       NULL       NULL       NULL       NULL       NULL
                                  NULL      NULL       NULL       NULL       NULL

 1 - 20     1 - 20     1 -  2     NULL      NULL       NULL      0.10E+00   0.00E+00    NULL       NULL       NULL       NULL       NULL
                                  NULL      NULL       NULL       NULL       NULL

 1 - 20     2 -  2     2 -  2    0.10E+03   NULL       NULL       NULL      -.10E+01    NULL       NULL       NULL       NULL       NULL
                                  NULL      NULL       NULL       NULL       NULL

 1 - 20     1 - 20     2 -  2     NULL      NULL       NULL       NULL       NULL       NULL       NULL       NULL       NULL       NULL
                                  NULL      NULL       NULL      0.10E-02   0.90E+02

 1 - 20     1 - 20     1 -  2     CUB      0.00E+00    LST        NULL       NULL       NULL       NULL       NULL       NULL       NULL
                                  NULL      NULL       NULL       NULL       NULL

CUBE ABOVE LIST/MAPS VARIABLE  0 WHICH IS PHI
```

```
INITIAL VALUES OF VARIABLE GRID SPACING.

  I       DELX      DELXI        DELY      DELYI       DELZ      DELZI
 ---  ---------- ----------  ---------- ----------  ---------- ----------
  1      1000.00 0.1000E-02     1000.00 0.1000E-02      100.00 0.1000E-01
  2      1000.00 0.1000E-02     1000.00 0.1000E-02      100.00 0.1000E-01
  3      1000.00 0.1000E-02     1000.00 0.1000E-02        0.00 0.0000E+00
  4      1000.00 0.1000E-02     1000.00 0.1000E-02        0.00 0.0000E+00
  5      1000.00 0.1000E-02     1000.00 0.1000E-02        0.00 0.0000E+00
  6      1000.00 0.1000E-02     1000.00 0.1000E-02        0.00 0.0000E+00
  7      1000.00 0.1000E-02     1000.00 0.1000E-02        0.00 0.0000E+00
  8      1000.00 0.1000E-02     1000.00 0.1000E-02        0.00 0.0000E+00
  9      1000.00 0.1000E-02     1000.00 0.1000E-02        0.00 0.0000E+00
 10      1000.00 0.1000E-02     1000.00 0.1000E-02        0.00 0.0000E+00
 11      1000.00 0.1000E-02     1000.00 0.1000E-02        0.00 0.0000E+00
 12      1000.00 0.1000E-02     1000.00 0.1000E-02        0.00 0.0000E+00
 13      1000.00 0.1000E-02     1000.00 0.1000E-02        0.00 0.0000E+00
 14      1000.00 0.1000E-02     1000.00 0.1000E-02        0.00 0.0000E+00
 15      1000.00 0.1000E-02     1000.00 0.1000E-02        0.00 0.0000E+00
 16      1000.00 0.1000E-02     1000.00 0.1000E-02        0.00 0.0000E+00
 17      1000.00 0.1000E-02     1000.00 0.1000E-02        0.00 0.0000E+00
 18      1000.00 0.1000E-02     1000.00 0.1000E-02        0.00 0.0000E+00
 19      1000.00 0.1000E-02     1000.00 0.1000E-02        0.00 0.0000E+00
 20      1000.00 0.1000E-02     1000.00 0.1000E-02        0.00 0.0000E+00


DIRECTIONAL TRANSMISSIVITY MULTIPLIERS

LAYER     FACTX        FACTY        FACTZ
-----  -----------  -----------  -----------
  1     0.1000E+01   0.1000E+01   0.1000E-06
  2     0.1000E+01   0.1000E+01   0.1000E-06
NODE GOES FROM CONFINED TO WATER TABLE    ROW=>     2 COL=>     2 LAYER=>     2 PP=>     0 TS=>     0 IT=>     0
NODE GOES FROM CONFINED TO WATER TABLE    ROW=>     3 COL=>     2 LAYER=>     2 PP=>     0 TS=>     0 IT=>     0
NODE GOES FROM CONFINED TO WATER TABLE    ROW=>     4 COL=>     2 LAYER=>     2 PP=>     0 TS=>     0 IT=>     0
NODE GOES FROM CONFINED TO WATER TABLE    ROW=>     5 COL=>     2 LAYER=>     2 PP=>     0 TS=>     0 IT=>     0
NODE GOES FROM CONFINED TO WATER TABLE    ROW=>     6 COL=>     2 LAYER=>     2 PP=>     0 TS=>     0 IT=>     0
NODE GOES FROM CONFINED TO WATER TABLE    ROW=>     7 COL=>     2 LAYER=>     2 PP=>     0 TS=>     0 IT=>     0
NODE GOES FROM CONFINED TO WATER TABLE    ROW=>     8 COL=>     2 LAYER=>     2 PP=>     0 TS=>     0 IT=>     0
NODE GOES FROM CONFINED TO WATER TABLE    ROW=>     9 COL=>     2 LAYER=>     2 PP=>     0 TS=>     0 IT=>     0
NODE GOES FROM CONFINED TO WATER TABLE    ROW=>    10 COL=>     2 LAYER=>     2 PP=>     0 TS=>     0 IT=>     0
NODE GOES FROM CONFINED TO WATER TABLE    ROW=>    11 COL=>     2 LAYER=>     2 PP=>     0 TS=>     0 IT=>     0
NODE GOES FROM CONFINED TO WATER TABLE    ROW=>    12 COL=>     2 LAYER=>     2 PP=>     0 TS=>     0 IT=>     0
NODE GOES FROM CONFINED TO WATER TABLE    ROW=>    13 COL=>     2 LAYER=>     2 PP=>     0 TS=>     0 IT=>     0
NODE GOES FROM CONFINED TO WATER TABLE    ROW=>    14 COL=>     2 LAYER=>     2 PP=>     0 TS=>     0 IT=>     0
NODE GOES FROM CONFINED TO WATER TABLE    ROW=>    15 COL=>     2 LAYER=>     2 PP=>     0 TS=>     0 IT=>     0
NODE GOES FROM CONFINED TO WATER TABLE    ROW=>    16 COL=>     2 LAYER=>     2 PP=>     0 TS=>     0 IT=>     0
NODE GOES FROM CONFINED TO WATER TABLE    ROW=>    17 COL=>     2 LAYER=>     2 PP=>     0 TS=>     0 IT=>     0
NODE GOES FROM CONFINED TO WATER TABLE    ROW=>    18 COL=>     2 LAYER=>     2 PP=>     0 TS=>     0 IT=>     0
NODE GOES FROM CONFINED TO WATER TABLE    ROW=>    19 COL=>     2 LAYER=>     2 PP=>     0 TS=>     0 IT=>     0
```

```
* * * * EXAMPLE FOR APPENDIX  * * * * TWO-AQUIFER PROBLEM WITH HEAD-DEPENDENT  AND SPECIFIED HEAD BOUNDARIES ****
                                          SOLUTION BY STRONGLY IMPLICIT PROCEDURE (SIP)
                                          ---------------------------------------------

                                                                                    TODAYS DATE (MDY) IS 11/18/81
   5 ITERATION PARAMETERS DEFINED

   1:  0.0000000E+00
   2:  0.8424233E+00
   3:  0.9751696E+00
   4:  0.9960873E+00
   5:  0.9993835E+00

ITERATION PARAMETERS (RHOP) WERE CALCULATED BY THE PROGRAM AS A FUNCTION OF GRID SIZE AND DIRECTIONAL TRANSMISSIVITIES.

TEMPORARY VARIABLES WERE:
WMAX = 0.99936E+00
RHO1 = 0.10000E+01  XPART= 0.76154E-02
RHO2 = 0.20000E+01  YPART= 0.50770E-02
RHO3 = 0.20000E+04  ZPART= 0.61655E-03

                                                 PUMPING PERIOD NO.   1:      1.00 DAYS
                                                 --------------------------------------

                                                   NUMBER OF TIME STEPS=     1
                                                         DELT IN HOURS = 0.24000E+02
                                                   MULTIPLIER FOR DELT = 0.10000E+01
&NEWPP  KP = 1,  NWEL = 0,  TMAX = 86400.,  NUMT = 1,  CDLT = 1.,  DELT = 86399.91360009,  QFAC = 100*1.,  &END

     0 WELL RECORDS TO BE PROCESSED
     0 WELLS ACCUMULATED INTO      0 NODES

NO PUMPING NODES DEFINED AT BEGINNING OF PUMPING PERIOD   1


NEW RIVER REACH DISCHARGE DATA AT BEGINNING OF PUMPING PERIOD   1

                    STREAM    DISCHARGE
                    ------    ---------
                       1    0.300E+01

                       2    0.200E+01

                       3    0.000E+00

                       4    0.000E+00

                       5    0.000E+00

&NEWRIV  RQ = 3.,  2.,  8*0.,  NR = 5,  NRC = 10,  6,  7,  6,  5,  5*0.  NADD = 2*3,  0,  5,  6*0,  RIVER = 185.,  180.,  175.,
 170.,  165.,  160.,  155.,  150.,  145.,  140.,  158.,  156.,  154.,  150.,  145.,  140.,  135.,  130.,  125.,  120.,  115.,
 110.,  105.,  130.,  125.,  120.,  130.,  125.,  120.,  115.,  110.,  105.,  95.,  90.,  66*0.,  VK = 23*1.E-8,  11*1.9026E-8,
 66*0.,  QMAX = 23*1.,  77*0.,  QMXOUT = 34*1..  66*0.,  &END
```

```
* * * * EXAMPLE FOR APPENDIX  * * * * TWO-AQUIFER PROBLEM WITH HEAD-DEPENDENT  AND SPECIFIED HEAD BOUNDARIES ****
                                                                                TODAYS DATE (MDY) IS 11/18/81
PUMPING PERIOD     1
TIMESTEP           1
ITERATION         47
NUMBER WELLS       0
DELT   0.863999E+05

-------------------------------------------------------------------------------------------------------------------------------------
LISTING FOR CUBE   1
         LAYER   2
          ROWS   1 TO   20
       COLUMNS   1 TO   20

-------------------------------------------------------------------------------------------------------------------------------------
LISTING OF PHI      FOR LAYER   2 WHERE LAYER   2 IS THE TOP AND LAYER 1 IS THE BOTTOM.

COLUMN NUMBERS:

I----  1---I I----  2---I I----  3---I I----  4---I I----  5---I I----  6---I I----  7---I I----  8---I I----  9---I I---- 10---I
I---- 11---I I---- 12---I I---- 13---I I---- 14---I I---- 15---I I---- 16---I I---- 17---I I---- 18---I I---- 19---I I---- 20---I

ROW NUMBER     1
 0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00
 0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00

ROW NUMBER     2
 0.00000E+00  0.10000E+03  0.10108E+03  0.10323E+03  0.10535E+03  0.10743E+03  0.10947E+03  0.11145E+03  0.11336E+03  0.11520E+03
 0.11695E+03  0.11958E+03  0.12010E+03  0.12147E+03  0.12268E+03  0.12369E+03  0.12449E+03  0.12505E+03  0.12533E+03  0.00000E+00

ROW NUMBER     3
 0.00000E+00  0.10000E+03  0.10109E+03  0.10324E+03  0.10537E+03  0.10746E+03  0.10951E+03  0.11151E+03  0.11344E+03  0.11529E+03
 0.11705E+03  0.11871E+03  0.12024E+03  0.12164E+03  0.12287E+03  0.12392E+03  0.12475E+03  0.12533E+03  0.12563E+03  0.00000E+00

ROW NUMBER     4
 0.00000E+00  0.10000E+03  0.10110E+03  0.10327E+03  0.10542E+03  0.10754E+03  0.10961E+03  0.11163E+03  0.11359E+03  0.11547E+03
 0.11727E+03  0.11896E+03  0.12053E+03  0.12198E+03  0.12326E+03  0.12437E+03  0.12526E+03  0.12589E+03  0.12623E+03  0.00000E+00

ROW NUMBER     5
 0.00000E+00  0.10000E+03  0.10111E+03  0.10331E+03  0.10549E+03  0.10764E+03  0.10975E+03  0.11181E+03  0.11381E+03  0.11574E+03
 0.11758E+03  0.11933E+03  0.12096E+03  0.12247E+03  0.12384E+03  0.12503E+03  0.12603E+03  0.12677E+03  0.12718E+03  0.00000E+00

ROW NUMBER     6
 0.00000E+00  0.10000E+03  0.10113E+03  0.10336E+03  0.10558E+03  0.10778E+03  0.10994E+03  0.11205E+03  0.11411E+03  0.11609E+03
 0.11800E+03  0.11981E+03  0.12152E+03  0.12312E+03  0.12459E+03  0.12591E+03  0.12707E+03  0.12799E+03  0.12855E+03  0.00000E+00

ROW NUMBER     7
 0.00000E+00  0.10000E+03  0.10114E+03  0.10341E+03  0.10568E+03  0.10794E+03  0.11016E+03  0.11234E+03  0.11446E+03  0.11652E+03
 0.11850E+03  0.12040E+03  0.12220E+03  0.12389E+03  0.12549E+03  0.12697E+03  0.12835E+03  0.12957E+03  0.13049E+03  0.00000E+00

ROW NUMBER     8
 0.00000E+00  0.10000E+03  0.10115E+03  0.10346E+03  0.10579E+03  0.10812E+03  0.11042E+03  0.11268E+03  0.11489E+03  0.11703E+03
 0.11910E+03  0.12109E+03  0.12298E+03  0.12478E+03  0.12650E+03  0.12816E+03  0.12980E+03  0.13147E+03  0.13336E+03  0.00000E+00

ROW NUMBER     9
 0.00000E+00  0.10000E+03  0.10113E+03  0.10347E+03  0.10589E+03  0.10832E+03  0.11072E+03  0.11308E+03  0.11538E+03  0.11761E+03
 0.11978E+03  0.12187E+03  0.12397E+03  0.12576E+03  0.12757E+03  0.12937E+03  0.13122E+03  0.13319E+03  0.13296E+03  0.00000E+00
```

```
ROW NUMBER   10
 0.00000E+00  0.10000E+03  0.10103E+03  0.10338E+03  0.10597E+03  0.10855E+03  0.11106E+03  0.11352E+03  0.11592E+03  0.11826E+03
 0.12054E+03  0.12276E+03  0.12487E+03  0.12683E+03  0.12868E+03  0.13055E+03  0.13253E+03  0.13243E+03  0.13235E+03  0.00000E+00

ROW NUMBER   11
 0.00000E+00  0.10000E+03  0.10063E+03  0.10304E+03  0.10606E+03  0.10883E+03  0.11144E+03  0.11401E+03  0.11653E+03  0.11898E+03
 0.12138E+03  0.12374E+03  0.12604E+03  0.12802E+03  0.12976E+03  0.13165E+03  0.13168E+03  0.13168E+03  0.13167E+03  0.00000E+00

ROW NUMBER   12
 0.00000E+00  0.10000E+03  0.10111E+03  0.10361E+03  0.10639E+03  0.10926E+03  0.11186E+03  0.11456E+03  0.11722E+03  0.11974E+03
 0.12225E+03  0.12481E+03  0.12754E+03  0.12945E+03  0.13071E+03  0.13078E+03  0.13089E+03  0.13096E+03  0.13099E+03  0.00000E+00

ROW NUMBER   13
 0.00000E+00  0.10000E+03  0.10127E+03  0.10389E+03  0.10662E+03  0.10941E+03  0.11218E+03  0.11514E+03  0.11805E+03  0.12050E+03
 0.12308E+03  0.12571E+03  0.12713E+03  0.12847E+03  0.12944E+03  0.12989E+03  0.13014E+03  0.13029E+03  0.13035E+03  0.00000E+00

ROW NUMBER   14
 0.00000E+00  0.10000E+03  0.10134E+03  0.10403E+03  0.10678E+03  0.10956E+03  0.11238E+03  0.11528E+03  0.11821E+03  0.12125E+03
 0.12345E+03  0.12541E+03  0.12680E+03  0.12789E+03  0.12870E+03  0.12921E+03  0.12952E+03  0.12971E+03  0.12979E+03  0.00000E+00

ROW NUMBER   15
 0.00000E+00  0.10000E+03  0.10137E+03  0.10412E+03  0.10689E+03  0.10968E+03  0.11251E+03  0.11537E+03  0.11827E+03  0.12119E+03
 0.12408E+03  0.12567E+03  0.12676E+03  0.12762E+03  0.12827E+03  0.12873E+03  0.12905E+03  0.12924E+03  0.12933E+03  0.00000E+00

ROW NUMBER   16
 0.00000E+00  0.10000E+03  0.10139E+03  0.10417E+03  0.10696E+03  0.10977E+03  0.11259E+03  0.11544E+03  0.11830E+03  0.12115E+03
 0.12393E+03  0.12645E+03  0.12698E+03  0.12755E+03  0.12804E+03  0.12842E+03  0.12870E+03  0.12888E+03  0.12897E+03  0.00000E+00

ROW NUMBER   17
 0.00000E+00  0.10000E+03  0.10141E+03  0.10421E+03  0.10701E+03  0.10982E+03  0.11265E+03  0.11549E+03  0.11834E+03  0.12120E+03
 0.12404E+03  0.12688E+03  0.12718E+03  0.12756E+03  0.12792E+03  0.12823E+03  0.12847E+03  0.12863E+03  0.12871E+03  0.00000E+00

ROW NUMBER   18
 0.00000E+00  0.10000E+03  0.10141E+03  0.10423E+03  0.10704E+03  0.10986E+03  0.11268E+03  0.11553E+03  0.11839E+03  0.12127E+03
 0.12417E+03  0.12713E+03  0.12732E+03  0.12758E+03  0.12786E+03  0.12812E+03  0.12833E+03  0.12847E+03  0.12855E+03  0.00000E+00

ROW NUMBER   19
 0.00000E+00  0.10000E+03  0.10142E+03  0.10423E+03  0.10705E+03  0.10987E+03  0.11270E+03  0.11555E+03  0.11842E+03  0.12131E+03
 0.12425E+03  0.12728E+03  0.12740E+03  0.12761E+03  0.12784E+03  0.12807E+03  0.12826E+03  0.12840E+03  0.12847E+03  0.00000E+00

ROW NUMBER   20
 0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00
 0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00
```

```
* * * * EXAMPLE FOR APPENDIX  * * * * TWO-AQUIFER PROBLEM WITH HEAD-DEPENDENT  AND SPECIFIED HEAD BOUNDARIES ****
                                                                                      TODAYS DATE (MDY) IS 11/18/81
PUMPING PERIOD    1
TIMESTEP          1
ITERATION        47
NUMBER WELLS      0
DELT   0.863999E+05

---------------------------------------------------------------------------------------------------------------------
LISTING FOR CUBE   1
          LAYER    1
           ROWS    1 TO   20
        COLUMNS    1 TO   20

---------------------------------------------------------------------------------------------------------------------
LISTING OF PHI      FOR LAYER   1 WHERE LAYER  2 IS THE TOP AND LAYER 1 IS THE BOTTOM.


COLUMN NUMBERS:

I----  1---I I----  2---I I----  3---I I----  4---I I----  5---I I----  6---I I----  7---I I----  8---I I----  9---I I---- 10---I
I---- 11---I I---- 12---I I---- 13---I I---- 14---I I---- 15---I I---- 16---I I---- 17---I I---- 18---I I---- 19---I I---- 20---I

ROW NUMBER    1
 0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00
 0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00

ROW NUMBER    2
 0.00000E+00  0.11602E+03  0.11605E+03  0.11610E+03  0.11615E+03  0.11622E+03  0.11629E+03  0.11637E+03  0.11645E+03  0.11653E+03
 0.11661E+03  0.11668E+03  0.11676E+03  0.11682E+03  0.11688E+03  0.11692E+03  0.11696E+03  0.11698E+03  0.11700E+03  0.00000E+00

ROW NUMBER    3
 0.00000E+00  0.11603E+03  0.11606E+03  0.11610E+03  0.11616E+03  0.11622E+03  0.11629E+03  0.11637E+03  0.11645E+03  0.11653E+03
 0.11661E+03  0.11669E+03  0.11676E+03  0.11682E+03  0.11688E+03  0.11693E+03  0.11696E+03  0.11699E+03  0.11700E+03  0.00000E+00

ROW NUMBER    4
 0.00000E+00  0.11603E+03  0.11606E+03  0.11610E+03  0.11616E+03  0.11622E+03  0.11630E+03  0.11637E+03  0.11646E+03  0.11654E+03
 0.11662E+03  0.11669E+03  0.11676E+03  0.11683E+03  0.11689E+03  0.11693E+03  0.11697E+03  0.11700E+03  0.11701E+03  0.00000E+00

ROW NUMBER    5
 0.00000E+00  0.11603E+03  0.11606E+03  0.11611E+03  0.11616E+03  0.11623E+03  0.11630E+03  0.11638E+03  0.11646E+03  0.11654E+03
 0.11662E+03  0.11670E+03  0.11677E+03  0.11684E+03  0.11690E+03  0.11695E+03  0.11698E+03  0.11701E+03  0.11702E+03  0.00000E+00

ROW NUMBER    6
 0.00000E+00  0.11604E+03  0.11607E+03  0.11611E+03  0.11617E+03  0.11624E+03  0.11631E+03  0.11639E+03  0.11647E+03  0.11655E+03
 0.11663E+03  0.11671E+03  0.11679E+03  0.11685E+03  0.11691E+03  0.11696E+03  0.11700E+03  0.11702E+03  0.11704E+03  0.00000E+00

ROW NUMBER    7
 0.00000E+00  0.11604E+03  0.11607E+03  0.11612E+03  0.11618E+03  0.11624E+03  0.11632E+03  0.11640E+03  0.11648E+03  0.11656E+03
 0.11665E+03  0.11672E+03  0.11680E+03  0.11687E+03  0.11692E+03  0.11697E+03  0.11701E+03  0.11704E+03  0.11705E+03  0.00000E+00

ROW NUMBER    8
 0.00000E+00  0.11605E+03  0.11608E+03  0.11613E+03  0.11618E+03  0.11625E+03  0.11633E+03  0.11641E+03  0.11649E+03  0.11658E+03
 0.11666E+03  0.11674E+03  0.11681E+03  0.11688E+03  0.11694E+03  0.11699E+03  0.11703E+03  0.11706E+03  0.11707E+03  0.00000E+00
```

```
ROW NUMBER    9
 0.00000E+00  0.11606E+03  0.11609E+03  0.11613E+03  0.11619E+03  0.11626E+03  0.11634E+03  0.11642E+03  0.11650E+03  0.11659E+03
 0.11667E+03  0.11675E+03  0.11683E+03  0.11690E+03  0.11696E+03  0.11701E+03  0.11705E+03  0.11707E+03  0.11709E+03  0.00000E+00

ROW NUMBER   10
 0.00000E+00  0.11606E+03  0.11610E+03  0.11614E+03  0.11620E+03  0.11627E+03  0.11635E+03  0.11643E+03  0.11652E+03  0.11660E+03
 0.11669E+03  0.11577E+03  0.11684E+03  0.11691E+03  0.11697E+03  0.11702E+03  0.11706E+03  0.11708E+03  0.11710E+03  0.00000E+00

ROW NUMBER   11
 0.00000E+00  0.11607E+03  0.11610E+03  0.11615E+03  0.11621E+03  0.11628E+03  0.11636E+03  0.11644E+03  0.11653E+03  0.11662E+03
 0.11670E+03  0.11678E+03  0.11686E+03  0.11693E+03  0.11698E+03  0.11703E+03  0.11707E+03  0.11709E+03  0.11711E+03  0.00000E+00

ROW NUMBER   12
 0.00000E+00  0.11608E+03  0.11611E+03  0.11616E+03  0.11622E+03  0.11629E+03  0.11637E+03  0.11645E+03  0.11654E+03  0.11663E+03
 0.11671E+03  0.11680E+03  0.11687E+03  0.11694E+03  0.11700E+03  0.11704E+03  0.11708E+03  0.11710E+03  0.11711E+03  0.00000E+00

ROW NUMBER   13
 0.00000E+00  0.11609E+03  0.11612E+03  0.11617E+03  0.11623E+03  0.11630E+03  0.11638E+03  0.11646E+03  0.11655E+03  0.11664E+03
 0.11673E+03  0.11681E+03  0.11688E+03  0.11695E+03  0.11700E+03  0.11705E+03  0.11708E+03  0.11711E+03  0.11712E+03  0.00000E+00

ROW NUMBER   14
 0.00000E+00  0.11609E+03  0.11613E+03  0.11617E+03  0.11624E+03  0.11631E+03  0.11639E+03  0.11647E+03  0.11656E+03  0.11665E+03
 0.11674E+03  0.11682E+03  0.11689E+03  0.11695E+03  0.11701E+03  0.11706E+03  0.11709E+03  0.11711E+03  0.11712E+03  0.00000E+00

ROW NUMBER   15
 0.00000E+00  0.11610E+03  0.11613E+03  0.11618E+03  0.11624E+03  0.11631E+03  0.11640E+03  0.11648E+03  0.11657E+03  0.11666E+03
 0.11674E+03  0.11682E+03  0.11690E+03  0.11696E+03  0.11702E+03  0.11706E+03  0.11709E+03  0.11712E+03  0.11713E+03  0.00000E+00

ROW NUMBER   16
 0.00000E+00  0.11610E+03  0.11614E+03  0.11619E+03  0.11625E+03  0.11632E+03  0.11640E+03  0.11649E+03  0.11658E+03  0.11666E+03
 0.11675E+03  0.11683E+03  0.11690E+03  0.11697E+03  0.11702E+03  0.11706E+03  0.11710E+03  0.11712E+03  0.11713E+03  0.00000E+00

ROW NUMBER   17
 0.00000E+00  0.11611E+03  0.11614E+03  0.11619E+03  0.11625E+03  0.11632E+03  0.11641E+03  0.11649E+03  0.11658E+03  0.11667E+03
 0.11675E+03  0.11683E+03  0.11691E+03  0.11697E+03  0.11702E+03  0.11706E+03  0.11710E+03  0.11712E+03  0.11713E+03  0.00000E+00

ROW NUMBER   18
 0.00000E+00  0.11611E+03  0.11614E+03  0.11619E+03  0.11625E+03  0.11633E+03  0.11641E+03  0.11650E+03  0.11658E+03  0.11667E+03
 0.11676E+03  0.11684E+03  0.11691E+03  0.11697E+03  0.11702E+03  0.11707E+03  0.11710E+03  0.11712E+03  0.11713E+03  0.00000E+00

ROW NUMBER   19
 0.00000E+00  0.11611E+03  0.11614E+03  0.11619E+03  0.11626E+03  0.11633E+03  0.11641E+03  0.11650E+03  0.11659E+03  0.11667E+03
 0.11676E+03  0.11684E+03  0.11691E+03  0.11697E+03  0.11702E+03  0.11707E+03  0.11710E+03  0.11712E+03  0.11713E+03  0.00000E+00

ROW NUMBER   20
 0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00
 0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00
```

```
EXAMPLE FOR APPENDIX  * * * * TWO-AQUIFER PROBLEM WITH HEAD-DEPENDENT  AND SPECIFIED HEAD BOUNDARIES ****
                                                                                  TODAYS DATE (MDY) IS 11/18/81
                ------------------------------------------------------------
                               TIME STEP NUMBER         1
                ------------------------------------------------------------

                 0.8639991E+05  IN SECONDS, SIZE OF TIMESTEP

                 0.8639991E+05  IN SECONDS, TOTAL SIMULATION TIME
                 0.1439999E+04  IN MINUTES
                 0.2399998E+02  IN HOURS
                 0.9999990E+00  IN DAYS
                 0.2739723E-02  IN YEARS

                 0.9999990E+00  IN DAYS, DURATION OF CURRENT PUMPING PERIOD
                 0.2739723E-02  IN YEARS

-------------------------------------------------------------------------------------------------------------------

                                                    MASS BALANCE

                CUMULATIVE
                 VOLUMES                                                                  RATES
  ----------------------------------------                              ----------------------------------------
      SOURCES            DISCHARGES                                          SOURCES            DISCHARGES
   -------------       -------------                                       -------------       -------------
   0.0000000E+00       0.3731497E+06       SPECIFIED-HEAD BOUNDARIES       0.0000000E+00       0.4318867E+01
                       0.0000000E+00          EVAPOTRANSPIRATION                               0.0000000E+00
   0.0000000E+00       0.0000000E+00               PUMPAGE                 0.0000000E+00       0.0000000E+00
   0.0000000E+00                                  RECHARGE                 0.0000000E+00
   0.4054126E+06       0.3225090E+05     INDUCED FLUX FROM/TO RIVERS       0.4692281E+01       0.3732747E+00
   0.0000000E+00                                   STORAGE                 0.0000000E+00
   0.4054126E+06       0.4054006E+06                 SUM                   0.4692281E+01       0.4692142E+01

-------------------------------------------------------------------------------------------------------------------

                0.1202102E+02             NET (SOURCE - DISCHARGE)                0.1391324E-03
                0.2965133E-02                PERCENT DIFFERENCE

-------------------------------------------------------------------------------------------------------------------

   0.0000000E+00       0.0000000E+00          SPECIFIED-HEAD NODE FLUX     0.0000000E+00       0.0000000E+00

-------------------------------------------------------------------------------------------------------------------
```

```
NON-ZERO FLOW RATES FROM SPECIFIED-HEAD NODES:

  LAYER  ROW  COL  RATE (L**3/T)
  -----  ---  ---  -------------

      2    2    2  -0.219709E+00
      2    3    2  -0.220655E+00
      2    4    2  -0.222498E+00
      2    5    2  -0.225116E+00
      2    6    2  -0.228259E+00
      2    7    2  -0.231386E+00
      2    8    2  -0.233177E+00
      2    9    2  -0.229949E+00
      2   10    2  -0.209879E+00
      2   11    2  -0.130156E+00
      2   12    2  -0.224298E+00
      2   13    2  -0.256948E+00
      2   14    2  -0.270817E+00
      2   15    2  -0.277862E+00
      2   16    2  -0.281883E+00
      2   17    2  -0.284287E+00
      2   18    2  -0.285674E+00
      2   19    2  -0.286314E+00

----------------------------------------------------------------------------------------------------------------

VERTICAL FLOW BETWEEN LAYERS.  POSITIVE VALUE INDICATES UPWARD FLOW,
 TO     FLOW
LAYER   RATE
-----   ------------

  2    -0.16189E-03

----------------------------------------------------------------------------------------------------------------
```

```
RIVER FLOW/DISCHARGE DATA:  34 RIVER NODES DEFINED FOR   5 RIVERS.
                                                 NODE   ROW   COL LAYER  RATE TO GW  RATE DOWNSTREAM
                                                -----  -----  -----  -----  -----------  ----------------

RIVER REACH   1 HAS   10 NODES.
                                                    1     8    19     2  0.5164E+00  0.2484E+01
                                                    2     9    18     2  0.4681E+00  0.2015E+01
                                                    3    10    17     2  0.4247E+00  0.1591E+01
                                                    4    11    16     2  0.3835E+00  0.1207E+01
                                                    5    12    15     2  0.3429E+00  0.8643E+00
                                                    6    12    14     2  0.3055E+00  0.5588E+00
                                                    7    12    13     2  0.2746E+00  0.2842E+00
                                                    8    13    12     2  0.2429E+00  0.4131E-01
                                                    9    13    11     2  0.4131E-01  0.0000E+00
                                                   10    13    10     2  0.0000E+00  0.0000E+00
RIVER REACH   2 HAS    6 NODES.
                                                   11    19    12     2  0.3072E+00  0.1693E+01
                                                   12    18    12     2  0.2887E+00  0.1404E+01
                                                   13    17    12     2  0.2712E+00  0.1133E+01
                                                   14    16    12     2  0.2355E+00  0.8975E+00
                                                   15    15    11     2  0.2092E+00  0.6883E+00
                                                   16    14    10     2  0.1875E+00  0.5007E+00
RIVER REACH   3 HAS    7 NODES.
                                                   17    13     9     2  0.1695E+00  0.3312E+00
                                                   18    13     8     2  0.1486E+00  0.1826E+00
                                                   19    13     7     2  0.1282E+00  0.5442E-01
                                                   20    12     6     2  0.5442E-01  0.0000E+00
                                                   21    12     5     0  0.0000E+00  0.0000E+00
                                                   22    11     4     2  0.0000E+00  0.0000E+00
                                                   23    11     3     2  0.0000E+00  0.0000E+00
RIVER REACH   4 HAS    6 NODES.
                                                   24    13    12     0  0.0000E+00  0.0000E+00
                                                   25    13    11     0  0.0000E+00  0.0000E+00
                                                   26    13    10     0 -0.9555E-02  0.9555E-02
                                                   27    14    12     0  0.0000E+00  0.9555E-02
                                                   28    14    11     0  0.0000E+00  0.9555E-02
                                                   29    14    10     0 -0.2370E-01  0.3325E-01
RIVER REACH   5 HAS    5 NODES.
                                                   30    13     9     0 -0.5796E-01  0.9122E-01
                                                   31    13     8     0 -0.9784E-01  0.1891E+00
                                                   32    13     7     0 -0.1366E+00  0.3256E+00
                                                   33    11     4     0 -0.1530E+00  0.4787E+00
                                                   34    11     3     0 -0.2023E+00  0.6810E+00

REMAINING DISCHARGE IN STREAM REACHES:

RIVER REACH  DISCHARGE
-----------  -----------
     1        0.0000E+00
     2        0.5007E+00
     3        0.0000E+00
     4        0.3325E-01
     5        0.6810E+00
```

```
MAXIMUM HEAD CHANGE FOR EACH ITERATION
--------------------------------------

ITER  ROW  COL LAY  HEAD CHANGE  ITER  ROW  COL LAY  HEAD CHANGE  ITER  ROW  COL LAY  HEAD CHANGE  ITER  ROW  COL LAY  HEAD CHANGE
---- ---- ---- --- ------------  ---- ---- ---- --- ------------  ---- ---- ---- --- ------------  ---- ---- ---- --- ------------
   1   19   19   2 -0.80089E+01     2    2   19   2 -0.83919E+01     3   19   19   2 -0.18899E+02     4    2   19   2 -0.27869E+02
   5    2    2   1 -0.39304E+02     6   14   10   2 -0.12929E+01     7   15   10   2 -0.13885E+01     8    2    4   1  0.98077E+00
   9    2    2   1  0.40135E+01    10    2   19   1  0.12133E+02    11   12    6   2  0.38816E+00    12    8   17   2 -0.23032E+00
  13    6   18   2 -0.40492E+00    14    2   19   2 -0.97718E+00    15   19   19   1  0.17174E+01    16   12    6   2 -0.87538E-01
  17   13   12   2  0.93347E-01    18   15   17   2  0.14880E+00    19   19   19   2  0.43111E+00    20    2   19   1  0.10858E+01
  21   14   10   2 -0.28696E-01    22    8   13   2 -0.24529E-01    23   19   19   1  0.36411E-01    24    2   18   2 -0.92573E-01
  25   19   19   1  0.31769E+00    26   13   11   2  0.86214E-02    27   14   12   2  0.48616E-02    28    2   19   1  0.11339E-01
  29   19   19   1  0.35045E-01    30    2   19   1  0.12729E+00    31   13   11   2  0.33244E-02    32   18   18   1  0.13512E-02
  33   19   19   1  0.41858E-02    34   19    2   1  0.12958E-01    35   19   19   1  0.46218E-01    36   13   11   2  0.10438E-02
  37    3   18   1  0.52182E-03    38    2   19   1  0.15800E-02    39    2    2   1  0.47478E-02    40    2   19   1  0.17539E-01
  41   13   11   2  0.47231E-03    42   18   18   1  0.18568E-03    43   19   19   1  0.57505E-03    44   19    2   1  0.18008E-02
  45   19   19   1  0.64627E-02    46   13   11   2  0.14044E-03    47    3   18   1  0.72834E-04

-------------------------------------------------------------------------------------------------------------------------------

TIME STEP :  1

-------------------------------------------------------------------------------------------------------------------------------

ITERATIONS: 47

-------------------------------------------------------------------------------------------------------------------------------
```

```
21:18:33     0.0000   CSP    AIR FORCE WEAPONS LABORATORY      KIRTLAND AFB, NM      11/18/81
21:18:33     0.0000   CSP
21:18:33     0.0000   CSP         CRAY-1  OPERATING SYSTEM         COS 1.09  ASSEMBLY DATE 11/18/81
21:18:33     0.0000   CSP
21:18:33     0.0000   CSP
21:18:33     0.0000   CSP    JOB,JN=WRUH28L,US=IN00000506,T=177.
21:18:34     0.0009   CSP    ACCOUNT.
21:18:34     0.0018   CSP    *.JOB,T=177.
21:18:34     0.0019   CSP    *.      ACQUIRE THE EXECUTABLE BINARIES                           ***************
21:18:34     0.0021   CSP    ACQUIRE,DN=BLD,PDN=CRA2020FD3D,ID=USGSPOS,DF=TR,UQ.
21:18:54     0.0022   SCP     21.19.35.ATTACH,CRA2020,CRA2020FD3D,ID=USGSPOS,MR
21:18:54     0.0022   SCP     21.19.35.=1.
21:18:54     0.0022   SCP     21.18.36.PF CYCLE NO. = 002
21:18:55     0.0022   SCP     21.18.43. BEGIN TRANSFER TO CRAY
21:18:55     0.0022   SCP     21.18.43. DATASET CRA2020
21:18:58     0.0022   SCP     21.18.45. COMPLETE TRANSFER TO CRAY
21:18:58     0.0022   SCP     21.18.45.      31744 64 BIT WORDS DF=TR
21:18:58     0.0022   EXP    DATASET CRA2020FD3D      RECEIVED FROM STATION   FB
21:18:58     0.0022   PDM    PD001 - ACCESS  CRA2020FD3D      ED=0001 COMPLETE
21:18:58     0.0023   CSP    DELETE,DN=BLD.
21:18:59     0.0024   CSP    RELEASE,DN=SIN.
21:18:59     0.0026   CSP    *.      ACQUIRE THE DATA DECK                                     ***************
21:18:58     0.0028   CSP    ACQUIRE,DN=FT05,PDN=CRADATAGLENN,ID=USGSPOS,UQ.
21:19:20     0.0029   SCP     21.19.03.ATTACH,CRADATA,CRADATAGLENN,ID=USGSPOS,M
21:19:20     0.0029   SCP     21.19.03.P=1.
21:19:20     0.0029   SCP     21.19.03.PF CYCLE NO. = 001
21:19:21     0.0029   SCP     21.19.09. BEGIN TRANSFER TO CRAY
21:19:21     0.0029   SCP     21.19.09. DATASET CRADATA
21:19:23     0.0029   SCP     21.19.11. COMPLETE TRANSFER TO CRAY
21:19:23     0.0029   SCP     21.19.11.          331 64 BIT WORDS DF=CB
21:19:23     0.0029   EXP    DATASET CRADATAGLENN     RECEIVED FROM STATION   FB
21:19:23     0.0029   PDM    PD001 - ACCESS  CRADATAGLENN     ED=0001 COMPLETE
21:19:23     0.0030   CSP    DELETE,DN=FT05.
21:19:23     0.0031   CSP    *.      SET UP FILE FOR TRANSIENT LEAKAGE - IF TRLEAK=.T.      *************
21:19:23     0.0032   CSP    *.ASSIGN,DN=LTRFIL,A=FT41,RDM,BS=44.
21:19:23     0.0033   CSP    *.WRITEDS,DN=LTRFIL,NR=2,RL=1620.
21:19:23     0.0034   CSP    *.      WHERE NR=2X(NLAYER-1)      2X(2-1)=2
21:19:23     0.0035   CSP    *.      RL=NODE X NROW X NCOL      5X18X18=1620.
21:19:23     0.0036   CSP    *.      ACQUIRE THE BAKIN FILE - IF RESTRT=.T.                    ***************
21:19:23     0.0037   CSP    *.ACQUIRE,DN=FT03,PDN=NEWABAKOUT,ID=USGSPOS,DF=TR,UQ.
21:19:23     0.0038   CSP    *.ASSIGN,DN=FT03,A=BAKIN.
21:19:23     0.0039   CSP    *.DELETE,DN=FT03.
21:19:23     0.0040   CSP    *.      LOAD EXECUTABLE CODE AND EXECUTE ON DATA                 ***************
21:19:23     0.0041   CSP    LDR,LIB=METALIB,SET=ZERO,DN=BLD.
21:19:26     0.2504   USER   LD010 - BEGIN EXECUTION
21:19:26     0.2508   USER   FT059 -
21:19:26     0.2508   USER   FT059 - OPERATOR - TO END PROGRAM, PLEASE SWITCH
21:19:26     0.2508   USER   FT059 -  SWITCH.1  STOPS AFTER ITERATION
21:19:25     0.2508   USER   FT059 -  SWITCH.2  STOPS AFTER TIMESTEP
21:19:26     0.2508   USER   FT059 -  SWITCH.6  DISPLAYS SIMULATION STATUS
21:19:26     0.2509   USER   FT059 -
21:19:26     0.2508   USER   FT059 - OPTIONS DEFINED FOR THIS RUN
21:19:26     0.2508   USER   FT059 -
21:19:26     0.2511   USER   FT059 - THIS RUN IS NOT A RESTART.
21:19:26     0.2511   USER   FT059 - THIS RUN WILL WRITE A BAKOUT FILE.
21:19:26     0.2548   USER   FT059 - LC-- OFFSET DEFINED BY PROGRAM.
21:19:26     0.2548   USER   FT059 -   15 VARIABLES DEFINED.
21:19:26     0.2548   USER   FT059 - THIS SIMULATION WILL BE RUN IN LCM.
21:19:26     0.2549   USER   FT059 - LCMFL SET TO 01706719 (D
21:19:26     0.2549   USER   FT059 - OPTION MASS BALANCE PRINT SELECTED.
21:19:26     0.2549   USER   FT059 - OPTION WATER TABLE SELECTED.
21:19:26     0.2549   USER   FT059 - OPTION EQN4 SELECTED.
21:19:26     0.2549   USER   FT059 - OPTION WELLS SET TO ZERO AT NEW P.P.
21:19:26     0.2979   USER   FT059 - LIST/MAP TYPES DEFINED =
21:19:26     0.2979   USER   FT059 - HYDROGRAPHS DEFINED =          0   CUB      CUB
21:19:26     0.3171   USER   FT059 - LAYER  2 INITIALIZED.
21:19:26     0.3393   USER   FT059 - LAYER  1 INITIALIZED.
```

```
21:19:26     0.3303    USER    FT059 - INITIALIZATION COMPLETE.
21:19:26     0.3523    USER    FT059 - ALTRAN COMPLETE.
21:19:26     0.3580    USER    FT059 - ITPARM COMPLETE.
21:19:26     0.3580    USER    FT059 - SCMFL SET TO 0000008 (CO
21:19:26     0.3580    USER    FT059 - BEGIN COMPUTING.
21:19:28     2.2105    USER    FT059 - RESTART FILE WILL BE WRITTEN ON BAKOUT
21:19:28     2.2107    USER    FT059 - BLK COMMON WRITTEN
21:19:28     2.2109    USER    FT059 - LAYER    1 WRITT
21:19:28     2.2112    USER    FT059 - LAYER    2 WRITT
21:19:28     2.2113    USER    FT059 - PP=  1 TS=  1 IT= 47 CP= 0.2211E+01
21:19:28     2.2113    USER    FT059 - NPER PUMPING PERIODS FINISHED.
21:19:28     2.2209    USER    FT059 - META SYSTEM PLOT TERMINATION
21:19:28     2.2209    USER    FT059 -        NUMBER OF PLOTS=    0
21:19:28     2.2210    USER    FT059 -        METASTAT  1, 1,      0,0000023111
21:19:28     2.2210    USER    FT063 -     STOP NORMAL        IN NMFD3D
21:19:28     2.2211    CSP     *.     ROUTE THE META FILE OUT TO TERMINAL - IF META OUTPUT *************
21:19:28     2.2212    CSP     ACCESS,DN=DIRECT.
21:19:28     2.2213    PDM     PD001 - ACCESS  DIRECT           ED=0002 COMPLETE
21:19:28     2.2214    CSP     DIRECT,I=FT99,DEV=PRINTER.
21:19:29     2.2310    USER    FTXXX         METASTAT 22, 1,      0,0000017052
21:19:29     2.2311    USER       STOP                 IN DIRECT
21:19:29     2.2312    CSP     *.     CATALOG BAKOUT AS A PERMANENT FILE ON CDC - IF SELRES=.T.**********
21:19:29     2.2313    CSP     REWIND,DN=FT04.
21:19:29     2.2316    CSP     DISPOSE,DN=FT04,SDN=NEWABAKOUT,ID=USGSPOS,DC=ST,RT=999,WAIT,DF=TR.
21:19:43     2.2318    SCP      21.19.30. BEGIN TRANSFER FROM CRAY
21:19:43     2.2318    SCP      21.19.31. DATASET NEWABAK
21:19:45     2.2318    SCP      21.19.33. COMPLETE TRANSFER FROM CRAY
21:19:45     2.2318    SCP      21.19.33.       37588 64 BIT WORDS DF=TR
21:20:11     2.2318    SCP      21.19.34.CATALOG,NEWABAK,NEWABAKOUT,ID=USGSPOS.
21:20:11     2.2318    SCP      21.19.34.INITIAL CATALOG
21:20:11     2.2318    SCP      21.19.51.RP = 010 DAYS
21:20:11     2.2318    SCP      21.19.51.CT ID=  USGSPOS PFN=NEWABAKOUT
21:20:11     2.2318    SCP      21.19.51.CT CY= 001  00040512 WORDS.
21:20:11     2.2319    CSP     AUDIT,ID=USGSPOS.
21:20:16     2.2704    USER    AU003 - NO DATASETS SELECTED
21:20:16     2.2704    CSP     EXIT.
21:20:16     2.2706    CSP     END OF JOB
21:20:16     2.2706    CSP
21:20:16     2.2706    CSP
21:20:16     2.2706    CSP
21:20:16     2.2707    USER        TIME WAITING FOR JXT-                   00:00:00.0001
21:20:16     2.2707    USER        OPEN CALLS-                                        20
21:20:16     2.2707    USER        CLOSE CALLS-                                       14
21:20:16     2.2707    USER        MEMORY RESIDENT DATASETS-                           0
21:20:16     2.2707    USER        TEMPORARY FILE SPACE USED-                         74 BLOCKS
21:20:16     2.2707    USER        PERMANENT FILE SPACE ACCESSED-                     64 BLOCKS
21:20:16     2.2707    USER        PERMANENT FILE SPACE SAVED-                         0 BLOCKS
21:20:16     2.2707    USER        MINIMUM MEMORY USED-                            55296 WORDS
21:20:16     2.2708    USER        MAXIMUM MEMORY USED-                           158720 WORDS
21:20:16     2.2708    USER        MEMORY INTEGRAL (EXECUTION TIME)-                   0.35721 MWDS-SEC
21:20:16     2.2708    USER        MEMORY INTEGRAL (I/O WAIT TIME)-                    0.23182 MWDS-SEC
21:20:16     2.2708    USER        BLOCKS RECEIVED FROM FRONT END-                    63
21:20:16     2.2708    USER        BLOCKS SENT TO THE FRONT END-                      74
21:20:16     2.2708    USER        TOTAL SBUS USED-                                    7
21:20:16     2.2708    CSP
21:20:16     2.2708    CSP             JOBNAME -------- WRUH2BL
21:20:16     2.2708    CSP             PROGRAMMER ---- GLENN408
21:20:16     2.2708    CSP             ORGANIZATION -- USGS
21:20:16     2.2709    CSP             PHONE NUMBER -- 7662810
21:20:16     2.2709    CSP
21:20:16     2.2709    CSP             TIME EXECUTING IN CPU - 00:00:02.2708
21:20:16     2.2709    CSP             TIME WAITING TO EXECUTE 00:01:37.8870
21:20:16     2.2709    CSP             TIME WAITING FOR I/O -- 00:00:01.9384
21:20:16     2.2709    CSP             MEMORY USAGE ---      0.58903 MWDS-SEC
21:20:16     2.2709    CSP             DISK BLOCKS MOVED -----        352
21:20:16     2.2709    CSP             PHYSICAL I/O REQUESTS -         66
21:20:16     2.2709    CSP             BILLING RATE ----------  B $1472.00/SBU-HOUR
21:20:16     2.2709    CSP             ESTIMATED COST --------        $2.85
```

Transient simulation

The job stream used to simulate a transient condition over four pumping periods is shown in table 8. Selected output produced by executing the job stream follows table 8. The dayfiles and initial-values output are not shown. Lists of PHI and flow at specified-head nodes have been deleted from the pumping-period output. For each pumping period, the output defining wells (specified-flow boundaries) and rivers (head-dependent flow boundaries) is followed by the mass balance and a summary of the simulated river routing.

In the first pumping period, three wells are defined; the first well irrigates 100 acres from a shallow well, the second withdraws 50 million gallons a year from a shallow well, and the third withdraws 400 million gallons a year from a deep well. Values of ROW, COL, LAYER, Q, and QTYPE are tabulated; one row of the table is generated for each record of input block 12. For each well, the adjusted Q is calculated as the product of Q and the appropriate QFAC. The first QFAC (-0.00424) converts million gallons a year to cubic feet per second. The second QFAC (-0.001381) results from assuming a net withdrawal of 1 acre-foot per year for each of the 100 acres. The three wells are then accumulated into the two well nodes; wells 1 and 2 are accumulated in the first well node; well 3 into the second well node. The discharge of the first reach of the river is changed from 3.0 to 1.0 cubic feet per second to represent the diversion of 2.0 cubic feet per second.

For the second pumping period, no new wells are added. River reaches 4 and 5 are removed by setting VK to zero. Maximum leakage (QMAX) from river reach 1 is reduced to 0.3 cubic foot per second.

For the third pumping period, a fourth well is added which recharges the upper layer with 0.1 cubic foot per second. The multiplying factors for the first three wells are changed to increase withdrawals at type 1 wells and decrease withdrawals at type 2 wells. River reaches 4 and 5 are activated again by making VK nonzero. The value of RIVER is changed at 2 nodes.

For the fourth pumping period, withdrawals are stopped for type 1 wells and the rates are changed for type 2 and type 3 wells. River reaches 4 and 5 are again removed. The value of RIVER is changed at another node.

Table 8. Job stream used for transient simulation with "rivers" and "wells" changing with time

```
WRUH1CRAJCL,T177,IO177,ST066.
ACCOUNT,******************************.
COMMENT.     COPY DATA TO A PERMANENT FILE ON CDC           ***************
REQUEST,DATA,*PF.
COPYBR,INPUT,DATA.
PURGE,OLDDATA,CRADATAGLENN,ID=USGSPOS,NA=1,LC=1.
RETURN,OLDDATA.
CATALOG,DATA,CRADATAGLENN,ID=USGSPOS.
COMMENT.     COPY CRAY CONTROL DECK TO A PERMANENT FILE ON CDC      ********
REQUEST,INCRA,*PF.
COPYBR,INPUT,INCRA.
PURGE,OLDRUN,CRAJCLGLENN,ID=USGSPOS,NA=1,LC=1.
RETURN,OLDRUN.
CATALOG,INCRA,CRAJCLGLENN,ID=USGSPOS.
COMMENT.     ZAP FILE TO CRAY FOR EXECUTION                   *************
ZAP,INCRA,F9,,IN.
$EOR
 $CONTROL
 PHISET=.TRUE.,
 ZRMBAL=.TRUE.,
 RESTRT=.TRUE.,
 $END
BAKIN               BAKOUT
 $INLIST
 SY(2)=0.15,
 CLSURE=0.00001,
 NPER=4,
 QFAC=-0.00424,
      -0.001381,
 $END
SYMBOLS
S          0.0001
H02       100
CH        -1
END
3D INPUT
                                 S
           2     2  H02          CH
END
ENDOFCUBES
```

Table 8. Job stream used for transient simulation with "rivers" and "wells" changing with time - Concluded

```
 $NEWPP   KP=1,  TMAX=3650,  NUMT=100, CDLT=1.0, DELT=4380,  $END
 $NEWELL  ROW=10,COL=15,LAYER=2, Q=100, QTYPE=2,  $END AC-FT/YR
 $NEWELL  ROW=10,COL=15,LAYER=2, Q=50, QTYPE=1,  $END MG/YR
 $NEWELL  ROW=10,COL=15,LAYER=1, Q=400, QTYPE=1,  $END MG/YR
 $NEWELL  ROW=0,  $END
 $NEWRIV  RO=1.0,2.0, $END
 $NEWPP KP=2, TMAX=3650, NUMT=100, CDLT=1.5, DELT=4380, $END
 $NEWELL ROW=0, $END
 $NEWRIV VK(24)=11*0.0,  QMAX=10*0.3,  $END
 $NEWPP KP=3, TMAX=3650, NUMT=100, CDLT=1.2, DELT=4380,
     QFAC=-0.005, -0.001, +0.001,                              $END
 $NEWELL ROW=10, COL=10, LAYER=2, Q=100, QTYPE=3, $END
 $NEWELL ROW=0, $END
 $NEWRIV VK(24)=11*1.9E-08,  RIVER(24)=140,135,  $END
 $NEWPP KP=4, TMAX=3650, NUMT=100, CDLT=1.2, DELT=4380,
     QFAC=0, -0.002, +0.002,                                    $END
 $NEWELL ROW=0, $END
 $NEWRIV VK(24)=11*0.0, RIVER(11)=150,  $END
$EOR
WRUH2CRAJCL,T177,I010,STCRA.
ACCOUNT,********************************.
JOB,T=177.
*.      ACQUIRE THE EXECUTABLE BINARIES                      ***************
ACQUIRE,DN=BLD,PDN=CRA2020FD3D,ID=USGSPOS,DF=TR,UQ.
DELETE,DN=BLD.
RELEASE,DN=$IN.
*.      ACQUIRE THE DATA DECK                                ***************
ACQUIRE,DN=FT05,PDN=CRADATAGLENN,ID=USGSPOS,UQ.
DELETE,DN=FT05.
*.      SET UP FILE FOR TRANSIENT LEAKAGE - IF TRLEAK=.T.      *************
*.ASSIGN,DN=LTRFIL,A=FT41,RDM,BS=44.
*.WRITEDS,DN=LTRFIL,NR=2,RL=1620.
*.      WHERE NR=2X(NLAYER-1)      2X(2-1)=2
*.      RL=MODE X NROW X NCOL      5X18X18=1620.
*.      ACQUIRE THE BAKIN FILE - IF RESTRT=.T.               ***************
ACQUIRE,DN=FT03,PDN=NEWABAKOUT,ID=USGSPOS,DF=TR,UQ.
ASSIGN,DN=FT03,A=BAKIN.
DELETE,DN=FT03.
*.      LOAD EXECUTABLE CODE AND EXECUTE ON DATA            ***************
LDR,LIB=METALIB,SET=ZERO,DN=BLD.
*.      ROUTE THE META FILE OUT TO TERMINAL - IF META OUTPUT *************
ACCESS,DN=DIRECT.
DIRECT,I=FT99,DEV=PRINTER.
*.      CATALOG BAKOUT AS A PERMANENT FILE ON CDC - IF SELRES=.T.**********
*.REWIND,DN=FT04.
*.DISPOSE,DN=FT04,SDN=NEWABAKOUT,ID=USGSPOS,DC=ST,RT=999,WAIT,DF=TR.
AUDIT,ID=USGSPOS.
EXIT.
$EOF
```

```
                                                 PUMPING PERIOD NO.    1:   3650.00 DAYS
                                                 -------------------------------------

                                                   NUMBER OF TIME STEPS=    20
                                                         DELT IN HOURS = 0.43800E+04
                                                   MULTIPLIER FOR DELT = 0.10000E+01
&NEWPP  KP = 1,  NWEL = -1,  TMAX = 315360000.,  NUMT = 20,  CDLT = 1.,  DELT = 15767999.99568,  QFAC = -4.24E-3,  -1.381E-3,
 98*1.,  &END

    10    15     2    100.0000     2
    10    15     2     50.0000     1
    10    15     1    400.0000     1
     0     0     0    400.0000   100
     3 WELL RECORDS TO BE PROCESSED
WELL    1 ADDED IN LAYER  2 ROW 10 COL 15 ADJUSTED Q=-0.13810E+00 QTYPE=  2 QFAC=-0.13810E-02
WELL    2 ADDED IN LAYER  2 ROW 10 COL 15 ADJUSTED Q=-0.21200E+00 QTYPE=  1 QFAC=-0.42400E-02
WELL    3 ADDED IN LAYER  1 ROW 10 COL 15 ADJUSTED Q=-0.16960E+01 QTYPE=  1 QFAC=-0.42400E-02
     3 WELLS ACCUMULATED INTO       2 NODES

SUMMARY OF PUMPING NODES AT BEGINNING OF PUMPING PERIOD     1

                         LAYER  ROW  COL  TOTAL PUMPAGE
                         -----  ---  ---  -------------

           WELL   1          2   10   15   -0.35010E+00
           WELL   2          1   10   15   -0.16960E+01



NEW RIVER REACH DISCHARGE DATA AT BEGINNING OF PUMPING PERIOD    1

                         STREAM    DISCHARGE
                         ------    ---------
                            1    0.100E+01

                            2    0.200E+01

                            3    0.000E+00

                            4    0.000E+00

                            5    0.000E+00

&NEWRIV  RQ = 1.,  2.,  8*0.,  NR = 5,  NRC = 10,  6,  7,  6,  5,  5*0,  NADD = 2*3,  0,  5,  6*0,  RIVER = 185.,  180.,  175.,
 170.,  165.,  160.,  155.,  150.,  145.,  140.,  158.,  156.,  154.,  150.,  145.,  140.,  135.,  130.,  125.,  120.,  115.,
 110.,  105.,  130.,  125.,  120.,  130.,  125.,  120.,  115.,  110.,  105.,  95.,  90.,  65*0.,  55.72869974769,  VK = 23*1.E-8,
 11*1.9026E-8,  66*0.,  QMAX = 23*1.,  77*0.,  QMXOUT = 34*1.,  66*0.,  &END
NODE GOES FROM CONFINED TO WATER TABLE     ROW=>   11 COL=>    3 LAYER=>    2 PP=>    1 TS=>   13 IT=>    2
```

```
EXAMPLE FOR APPENDIX  * * * * TWO-AQUIFER PROBLEM WITH HEAD-DEPENDENT  AND SPECIFIED HEAD BOUNDARIES ****
                                                                                  TODAYS DATE (MDY) IS 11/18/81
                ------------------------------------------------------------
                               TIME STEP NUMBER        20
                ------------------------------------------------------------

                 0.1576800E+08  IN SECONDS, SIZE OF TIMESTEP

                 0.3153600E+09  IN SECONDS, TOTAL SIMULATION TIME
                 0.5256000E+07  IN MINUTES
                 0.8760000E+05  IN HOURS
                 0.3650000E+04  IN DAYS
                 0.1000000E+02  IN YEARS

                 0.3650000E+04  IN DAYS, DURATION OF CURRENT PUMPING PERIOD
                 0.1000000E+02  IN YEARS

------------------------------------------------------------------------------------------------------------

                                                MASS BALANCE

                CUMULATIVE
                  VOLUMES                                                                RATES
 ---------------------------------------                                ---------------------------------------
      SOURCES           DISCHARGES                                         SOURCES           DISCHARGES
   -------------      -------------                                     -------------      -------------
   0.4263837E+08      0.7319711E+09      SPECIFIED-HEAD BOUNDARIES         0.1466262E+00      0.1373849E+01
                      0.0000000E+00          EVAPOTRANSPIRATION                                0.0000000E+00
   0.0000000E+00      0.6452581E+09               PUMPAGE                   0.0000000E+00      0.2046100E+01
   0.0000000E+00                                  RECHARGE                  0.0000000E+00
   0.9390711E+09      0.1108258E+09    INDUCED FLUX FROM/TO RIVERS          0.3000000E+01      0.2960577E+00
   0.5063402E+09                                  STORAGE                   0.5693682E+00
   0.1488050E+10      0.1488055E+10                 SUM                     0.3715994E+01      0.3716007E+01

------------------------------------------------------------------------------------------------------------

             -0.5419761E+04                NET (SOURCE - DISCHARGE)                  -0.1258873E-04
             -0.3642191E-03                    PERCENT DIFFERENCE

------------------------------------------------------------------------------------------------------------

   0.0000000E+00      0.0000000E+00          SPECIFIED-HEAD NODE FLUX       0.0000000E+00      0.0000000E+00

------------------------------------------------------------------------------------------------------------
```

```
RIVER FLOW/DISCHARGE DATA:  34 RIVER NODES DEFINED FOR   5 RIVERS.
                                           NODE   ROW   COL LAYER  RATE TO GW  RATE DOWNSTREAM
                                          ----- ----- ----- ----- ----------- ----------------

RIVER REACH   1 HAS   10 NODES.

                                              1     8    19     2  0.6893E+00  0.3107E+00
                                              2     9    18     2  0.3107E+00  0.0000E+00
                                              3    10    17     2  0.0000E+00  0.0000E+00
                                              4    11    16     2  0.0000E+00  0.0000E+00
                                              5    12    15     2  0.0000E+00  0.0000E+00
                                              6    12    14     2  0.0000E+00  0.0000E+00
                                              7    12    13     2  0.0000E+00  0.0000E+00
                                              8    13    12     2  0.0000E+00  0.0000E+00
                                              9    13    11     2  0.0000E+00  0.0000E+00
                                             10    13    10     2  0.0000E+00  0.0000E+00
RIVER REACH   2 HAS    6 NODES.

                                             11    19    12     2  0.4124E+00  0.1588E+01
                                             12    18    12     2  0.3956E+00  0.1192E+01
                                             13    17    12     2  0.3819E+00  0.8100E+00
                                             14    16    12     2  0.3526E+00  0.4575E+00
                                             15    15    11     2  0.3238E+00  0.1337E+00
                                             16    14    10     2  0.1337E+00  0.0000E+00
RIVER REACH   3 HAS    7 NODES.

                                             17    13     9     2  0.0000E+00  0.0000E+00
                                             18    13     8     2  0.0000E+00  0.0000E+00
                                             19    13     7     2  0.0000E+00  0.0000E+00
                                             20    12     6     2  0.0000E+00  0.0000E+00
                                             21    12     5     0  0.0000E+00  0.0000E+00
                                             22    11     4     2  0.0000E+00  0.0000E+00
                                             23    11     3     2  0.0000E+00  0.0000E+00
RIVER REACH   4 HAS    6 NODES.

                                             24    13    12     0  0.0000E+00  0.0000E+00
                                             25    13    11     0  0.0000E+00  0.0000E+00
                                             26    13    10     0  0.0000E+00  0.0000E+00
                                             27    14    12     0  0.0000E+00  0.0000E+00
                                             28    14    11     0  0.0000E+00  0.0000E+00
                                             29    14    10     0  0.0000E+00  0.0000E+00
RIVER REACH   5 HAS    5 NODES.

                                             30    13     9     0  0.0000E+00  0.0000E+00
                                             31    13     8     0  0.0000E+00  0.0000E+00
                                             32    13     7     0  0.0000E+00  0.0000E+00
                                             33    11     4     0 -0.1058E+00  0.1058E+00
                                             34    11     3     0 -0.1903E+00  0.2961E+00
REMAINING DISCHARGE IN STREAM REACHES:

RIVER REACH  DISCHARGE
-----------  -----------
     1        0.0000E+00
     2        0.0000E+00
     3        0.0000E+00
     4        0.0000E+00
     5        0.2961E+00

-----------------------------------------------------------------------------------------------
```

```
                                                         PUMPING PERIOD NO.   2:   3650.00 DAYS
                                                         -------------------------------------

                                                          NUMBER OF TIME STEPS=      6
                                                                DELT IN HOURS = 0.28102E+04
                                                          MULTIPLIER FOR DELT = 0.15000E+01
&NEWPP  KP = 2,  NWEL = -1,  TMAX = 315360000.,  NUMT = 6,  COLT = 1.5,  DELT = 10116812.0283,  QFAC = -4.24E-3,  -1.381E-3,
 98*1.,  &END

     0     0     0     -1.6960   100
     3 WELL RECORDS TO BE PROCESSED
WELL    1 ADDED IN LAYER  2 ROW 10 COL 15 ADJUSTED Q=-0.13810E+00 QTYPE=  2 QFAC=-0.13810E-02
WELL    2 ADDED IN LAYER  2 ROW 10 COL 15 ADJUSTED Q=-0.21200E+00 QTYPE=  1 QFAC=-0.42400E-02
WELL    3 ADDED IN LAYER  1 ROW 10 COL 15 ADJUSTED Q=-0.16960E+01 QTYPE=  1 QFAC=-0.42400E-02
     3 WELLS ACCUMULATED INTO      2 NODES



SUMMARY OF PUMPING NODES AT BEGINNING OF PUMPING PERIOD    2

                    LAYER  ROW  COL  TOTAL PUMPAGE
                    -----  ---  ---  -------------

         WELL   1       2   10   15    -0.35010E+00
         WELL   2       1   10   15    -0.16960E+01



NEW RIVER REACH DISCHARGE DATA A: BEGINNING OF PUMPING PERIOD   2

                    STREAM    DISCHARGE
                    ------    ---------
                       1    0.100E+01

                       2    0.200E+01

                       3    0.000E+00

                       4    0.000E+00

                       5    0.000E+00

&NEWRIV  RQ = 1.,  2.,  8*0.,  NR = 5,  NRC = 10,  6,  7,  6,  5,  5*0,  NADD = 2*3,  0,  5,  6*0,  RIVER = 185.,  180.,  175.,
 170.,  165.,  160.,  155.,  150.,  145.,  140.,  158.,  156.,  154.,  150.,  145.,  140.,  135.,  130.,  125.,  120.,  115.,
 110.,  105.,  130.,  125.,  120.,  130.,  125.,  120.,  115.,  110.,  105.,  95.,  90.,  65*0.,  329.8784611315,  VK = 23*1.E-8,
 77*0.,  QMAX = 10*0.3,  13*1.,  77*0.,  QMXOUT = 34*1.,  66*0.,  &END
```

```
 EXAMPLE FOR APPENDIX  * * * * TWO-AQUIFER PROBLEM WITH HEAD-DEPENDENT  AND SPECIFIED HEAD BOUNDARIES ****
                                                                                TODAYS DATE (MDY) IS 11/18/81
                 ------------------------------------------------------------
                                TIME STEP NUMBER         6
                 ------------------------------------------------------------

                  0.1152368E+09  IN SECONDS, SIZE OF TIMESTEP

                  0.6307200E+09  IN SECONDS, TOTAL SIMULATION TIME
                  0.1051200E+08  IN MINUTES
                  0.1752000E+06  IN HOURS
                  0.7300000E+04  IN DAYS
                  0.2000000E+02  IN YEARS

                  0.3650000E+04  IN DAYS, DURATION OF CURRENT PUMPING PERIOD
                  0.1000000E+02  IN YEARS
-------------------------------------------------------------------------------------------------------------------

                                                   MASS BALANCE

                 CUMULATIVE
                   VOLUMES                                                              RATES
  ----------------------------------------                              ----------------------------------------
        SOURCES           DISCHARGES                                         SOURCES           DISCHARGES
     -------------       -------------                                      -------------      -------------
     0.9004005E+08       0.1154320E+10       SPECIFIED-HEAD BOUNDARIES        0.1516613E+00      0.1221722E+01
                         0.0000000E+00          EVAPOTRANSPIRATION                                0.0000000E+00
     0.0000000E+00       0.1290516E+10               PUMPAGE                  0.0000000E+00      0.2046100E+01
     0.0000000E+00                                   RECHARGE                 0.0000000E+00
     0.1885151E+10       0.1108258E+09     INDUCED FLUX FROM/TO RIVERS        0.3000000E+01      0.0000000E+00
     0.5804591E+09                                   STORAGE                  0.1161400E+00
     0.2555650E+10       0.2555662E+10                 SUM                    0.3267801E+01      0.3267822E+01
-------------------------------------------------------------------------------------------------------------------

                -0.1171186E+05              NET (SOURCE - DISCHARGE)                    -0.2041600E-04
                -0.4582732E-03                  PERCENT DIFFERENCE

-------------------------------------------------------------------------------------------------------------------

     0.0000000E+00       0.0000000E+00          SPECIFIED-HEAD NODE FLUX      0.0000000E+00      0.0000000E+00

-------------------------------------------------------------------------------------------------------------------
```

```
RIVER FLOW/DISCHARGE DATA:  34 RIVER NODES DEFINED FOR   5 RIVERS.
                                      NODE   ROW   COL LAYER  RATE TO GW  RATE DOWNSTREAM
                                     ----- ----- ----- ----- ----------- ----------------

RIVER REACH   1 HAS   10 NODES.

                                         1     8    19     2  0.3000E+00  0.7000E+00
                                         2     9    18     2  0.3000E+00  0.4000E+00
                                         3    10    17     2  0.3000E+00  0.1000E+00
                                         4    11    16     2  0.1000E+00  0.0000E+00
                                         5    12    15     2  0.0000E+00  0.0000E+00
                                         6    12    14     2  0.0000E+00  0.0000E+00
                                         7    12    13     2  0.0000E+00  0.0000E+00
                                         8    13    12     2  0.0000E+00  0.0000E+00
                                         9    13    11     2  0.0000E+00  0.0000E+00
                                        10    13    10     2  0.0000E+00  0.0000E+00
RIVER REACH   2 HAS    6 NODES.

                                        11    19    12     2  0.4270E+00  0.1573E+01
                                        12    18    12     2  0.4104E+00  0.1163E+01
                                        13    17    12     2  0.3970E+00  0.7655E+00
                                        14    16    12     2  0.3682E+00  0.3973E+00
                                        15    15    11     2  0.3394E+00  0.5792E-01
                                        16    14    10     2  0.5792E-01  0.0000E+00
RIVER REACH   3 HAS    7 NODES.

                                        17    13     9     2  0.0000E+00  0.0000E+00
                                        18    13     8     2  0.0000E+00  0.0000E+00
                                        19    13     7     2  0.0000E+00  0.0000E+00
                                        20    12     6     2  0.0000E+00  0.0000E+00
                                        21    12     5     0  0.0000E+00  0.0000E+00
                                        22    11     4     2  0.0000E+00  0.0000E+00
                                        23    11     3     2  0.0000E+00  0.0000E+00
RIVER REACH   4 HAS    6 NODES.

                                        24    13    12     0  0.0000E+00  0.0000E+00
                                        25    13    11     0  0.0000E+00  0.0000E+00
                                        26    13    10     0  0.0000E+00  0.0000E+00
                                        27    14    12     0  0.0000E+00  0.0000E+00
                                        28    14    11     0  0.0000E+00  0.0000E+00
                                        29    14    10     0  0.0000E+00  0.0000E+00
RIVER REACH   5 HAS    5 NODES.

                                        30    13     9     0  0.0000E+00  0.0000E+00
                                        31    13     8     0  0.0000E+00  0.0000E+00
                                        32    13     7     0  0.0000E+00  0.0000E+00
                                        33    11     4     0  0.0000E+00  0.0000E+00
                                        34    11     3     0  0.0000E+00  0.0000E+00
REMAINING DISCHARGE IN STREAM REACHES:

RIVER REACH  DISCHARGE
----------- -----------
     1        0.0000E+00
     2        0.0000E+00
     3        0.0000E+00
     4        0.0000E+00
     5        0.0000E+00

------------------------------------------------------------------------------------------
```

```
                                                                 PUMPING PERIOD NO.   3:   3650.00 DAYS
                                                                 -------------------------------------

                                                                   NUMBER OF TIME STEPS=     9
                                                                         DELT IN HOURS = 0.35098E+04
                                                                   MULTIPLIER FOR DELT = 0.12000E+01
&NEWPP  KP = 3,  NWEL = -1,  TMAX = 315360000.,  NUMT = 9,  CDLT = 1.2,  DELT = 12635292.52476,  QFAC = -5.E-3,  -1.E-3,  1.E-3,
 97*1.,  &END

    10     10      2     100.0000      3
     0      0      0     100.0000    100
     4 WELL RECORDS TO BE PROCESSED
WELL   1 ADDED IN LAYER  2 ROW 10 COL 15 ADJUSTED Q=-0.10000E+00 QTYPE=  2 QFAC=-0.10000E-02
WELL   2 ADDED IN LAYER  2 ROW 10 COL 15 ADJUSTED Q=-0.25000E+00 QTYPE=  1 QFAC=-0.50000E-02
WELL   3 ADDED IN LAYER  1 ROW 10 COL 15 ADJUSTED Q=-0.20000E+01 QTYPE=  1 QFAC=-0.50000E-02
WELL   4 ADDED IN LAYER  2 ROW 10 COL 10 ADJUSTED Q= 0.10000E+00 QTYPE=  3 QFAC= 0.10000E-02
     4 WELLS ACCUMULATED INTO      3 NODES


SUMMARY OF PUMPING NODES AT BEGINNING OF PUMPING PERIOD    3

                    LAYER  ROW  COL  TOTAL PUMPAGE
                    -----  ---  ---  -------------

        WELL   1        2   10   15   -0.35000E+00
        WELL   2        1   10   15   -0.20000E+01
        WELL   3        2   10   10    0.10000E+00



NEW RIVER REACH DISCHARGE DATA AT BEGINNING OF PUMPING PERIOD   3

                    STREAM    DISCHARGE
                    ------    ---------
                       1    0.100E+01

                       2    0.200E+01

                       3    0.000E+00

                       4    0.000E+00

                       5    0.000E+00

&NEWRIV  RQ = 1.,  2.,  8*0.,  NR = 5,  NRC = 10,  6,  7,  6,  5,  5*0,  NADD = 2*3,  0,  5,  6*0,  RIVER = 185.,  180.,  175.,
 170.,  165.,  160.,  155.,  150.,  145.,  140.,  158.,  156.,  154.,  150.,  145.,  140.,  135.,  130.,  125.,  120.,  115.,
 110.,  105.,  140.,  135.,  120.,  130.,  125.,  120.,  115.,  110.,  105.,  95.,  90.,  65*0.,  329.8784611315,  VK = 23*1.E-8,
 11*1.9E-8,  66*0.,  QMAX = 10*0.3,  13*1.,  77*0.,  QMXOUT = 34*1.,  66*0.,  &END
```

```
EXAMPLE FOR APPENDIX  * * * * TWO-AQUIFER PROBLEM WITH HEAD-DEPENDENT  AND SPECIFIED HEAD BOUNDARIES ****
                                                                          TODAYS DATE (MDY) IS 11/18/81
                ------------------------------------------------------------
                              TIME STEP NUMBER         9
                ------------------------------------------------------------

                 0.6519528E+08  IN SECONDS, SIZE OF TIMESTEP

                 0.9460800E+09  IN SECONDS, TOTAL SIMULATION TIME
                 0.1576800E+08  IN MINUTES
                 0.2628000E+06  IN HOURS
                 0.1095000E+05  IN DAYS
                 0.3000000E+02  IN YEARS

                 0.3650000E+04  IN DAYS, DURATION OF CURRENT PUMPING PERIOD
                 0.1000000E+02  IN YEARS

-----------------------------------------------------------------------------------------------------------------

                                                   MASS BALANCE

                CUMULATIVE
                  VOLUMES                                                                   RATES
 ----------------------------------------                              ----------------------------------------
      SOURCES            DISCHARGES                                         SOURCES            DISCHARGES
   -------------       -------------                                    -------------       -------------
   0.1755693E+09       0.1421383E+10     SPECIFIED-HEAD BOUNDARIES      0.2823576E+00       0.7910466E+00
                       0.0000000E+00        EVAPOTRANSPIRATION                              0.0000000E+00
   0.3153600E+08       0.2031612E+10              PUMPAGE               0.1000000E+00       0.2350000E+01
   0.0000000E+00                                  RECHARGE              0.0000000E+00
   0.2831231E+10       0.2023794E+09   INDUCED FLUX FROM/TO RIVERS      0.3000000E+01       0.2897019E+00
   0.6170206E+09                                  STORAGE               0.4837683E-01
   0.3655357E+10       0.3655374E+10               SUM                  0.3430734E+01       0.3430748E+01

-----------------------------------------------------------------------------------------------------------------

             -0.1717946E+05                NET (SOURCE - DISCHARGE)                   -0.1401786E-04
             -0.4699802E-03                   PERCENT DIFFERENCE

-----------------------------------------------------------------------------------------------------------------

   0.0000000E+00       0.0000000E+00         SPECIFIED-HEAD NODE FLUX       0.0000000E+00       0.0000000E+00

-----------------------------------------------------------------------------------------------------------------
```

```
RIVER FLOW/DISCHARGE DATA:  34 RIVER NODES DEFINED FOR   5 RIVERS.
                                              NODE   ROW   COL LAYER  RATE TO GW  RATE DOWNSTREAM
                                             ----- ----- ----- ----- ----------- ----------------

RIVER REACH   1 HAS   10 NODES.
                                                 1     8    19     2  0.3000E+00  0.7000E+00
                                                 2     9    18     2  0.3000E+00  0.4000E+00
                                                 3    10    17     2  0.3000E+00  0.1000E+00
                                                 4    11    16     2  0.1000E+00  0.0000E+00
                                                 5    12    15     2  0.0000E+00  0.0000E+00
                                                 6    12    14     2  0.0000E+00  0.0000E+00
                                                 7    12    13     2  0.0000E+00  0.0000E+00
                                                 8    13    12     2  0.0000E+00  0.0000E+00
                                                 9    13    11     2  0.0000E+00  0.0000E+00
                                                10    13    10     2  0.0000E+00  0.0000E+00
RIVER REACH   2 HAS    6 NODES.
                                                11    19    12     2  0.4355E+00  0.1565E+01
                                                12    18    12     2  0.4189E+00  0.1146E+01
                                                13    17    12     2  0.4057E+00  0.7399E+00
                                                14    16    12     2  0.3771E+00  0.3628E+00
                                                15    15    11     2  0.3480E+00  0.1480E-01
                                                16    14    10     2  0.1480E-01  0.0000E+00
RIVER REACH   3 HAS    7 NODES.
                                                17    13     9     2  0.0000E+00  0.0000E+00
                                                18    13     8     2  0.0000E+00  0.0000E+00
                                                19    13     7     2  0.0000E+00  0.0000E+00
                                                20    12     6     2  0.0000E+00  0.0000E+00
                                                21    12     5     0  0.0000E+00  0.0000E+00
                                                22    11     4     2  0.0000E+00  0.0000E+00
                                                23    11     3     2  0.0000E+00  0.0000E+00
RIVER REACH   4 HAS    6 NODES.
                                                24    13    12     0  0.0000E+00  0.0000E+00
                                                25    13    11     0  0.0000E+00  0.0000E+00
                                                26    13    10     0  0.0000E+00  0.0000E+00
                                                27    14    12     0  0.0000E+00  0.0000E+00
                                                28    14    11     0  0.0000E+00  0.0000E+00
                                                29    14    10     0  0.0000E+00  0.0000E+00
RIVER REACH   5 HAS    5 NODES.
                                                30    13     9     0  0.0000E+00  0.0000E+00
                                                31    13     8     0  0.0000E+00  0.0000E+00
                                                32    13     7     0  0.0000E+00  0.0000E+00
                                                33    11     4     0 -0.9970E-01  0.9970E-01
                                                34    11     3     0 -0.1900E+00  0.2897E+00
REMAINING DISCHARGE IN STREAM REACHES:

RIVER REACH  DISCHARGE
----------- ----------
     1       0.0000E+00
     2       0.0000E+00
     3       0.0000E+00
     4       0.0000E+00
     5       0.2897E+00

-----------------------------------------------------------------------------------------------
```

```
                                                       PUMPING PERIOD NO.   4:   3650.00 DAYS
                                                       ------------------------------------

                                                        NUMBER OF TIME STEPS=     9
                                                              DELT IN HOURS = 0.35098E+04
                                                        MULTIPLIER FOR DELT = 0.12000E+01
&NEWPP  KP = 4,  NWEL = -1,  TMAX = 315360000.,  NUMT = 9,  CDLT = 1.2,  DELT = 12635282.52476,  QFAC = 0.,  -2.E-3,  2.E-3,
 97*1.,  &END

     0      0      0      0.1000   100
     4 WELL RECORDS TO BE PROCESSED
WELL    1 ADDED IN LAYER  2 ROW 10 COL 15 ADJUSTED Q=-0.20000E+00 QTYPE=  2 QFAC=-0.20000E-02
WELL    2 ADDED IN LAYER  2 ROW 10 COL 15 ADJUSTED Q= 0.00000E+00 QTYPE=  1 QFAC= 0.00000E+00
WELL    3 ADDED IN LAYER  1 ROW 10 COL 15 ADJUSTED Q= 0.00000E+00 QTYPE=  1 QFAC= 0.00000E+00
WELL    4 ADDED IN LAYER  2 ROW 10 COL 10 ADJUSTED Q= 0.20000E+00 QTYPE=  3 QFAC= 0.20000E-02
     4 WELLS ACCUMULATED INTO      3 NODES


SUMMARY OF PUMPING NODES AT BEGINNING OF PUMPING PERIOD    4

                    LAYER  ROW  COL  TOTAL PUMPAGE
                    -----  ---  ---  -------------

         WELL  1        2   10   15   -0.20000E+00
         WELL  2        1   10   15    0.00000E+00
         WELL  3        2   10   10    0.20000E+00


NEW RIVER REACH DISCHARGE DATA AT BEGINNING OF PUMPING PERIOD   4

                    STREAM    DISCHARGE
                    ------    ---------
                       1    0.100E+01

                       2    0.200E+01

                       3    0.000E+00

                       4    0.000E+00

                       5    0.000E+00

&NEWRIV  RQ = 1.,  2.,  8*0.,  NR = 5,  NRC = 10,  6,  7,  6,  5,  5*0,  NADD = 2*3,  0,  5,  6*0,  RIVER = 185.,  180.,  175.,
 170.,  165.,  160.,  155.,  150.,  145.,  140.,  150.,  156.,  154.,  150.,  145.,  140.,  135.,  130.,  125.,  120.,  115.,
 110.,  105.,  140.,  135.,  120.,  130.,  125.,  120.,  115.,  110.,  105.,  95.,  90.,  65*0.,  405.1837304969,  VK = 23*1.E-8,
 77*0.,  QMAX = 10*0.3,  13*1.,  77*0.,  QMXOUT = 34*1.,  66*0.,  &END
```

```
EXAMPLE FOR APPENDIX  * * * * TWO-AQUIFER PROBLEM WITH HEAD-DEPENDENT  AND SPECIFIED HEAD BOUNDARIES ****
                                                                              TODAYS DATE (MDY) IS 11/18/81
                ------------------------------------------------------------
                               TIME STEP NUMBER         9
                ------------------------------------------------------------

                 0.6519528E+08  IN SECONDS, SIZE OF TIMESTEP

                 0.1261440E+10  IN SECONDS, TOTAL SIMULATION TIME
                 0.2102400E+08  IN MINUTES
                 0.3504000E+06  IN HOURS
                 0.1460000E+05  IN DAYS
                 0.4000000E+02  IN YEARS

                 0.3650000E+04  IN DAYS, DURATION OF CURRENT PUMPING PERIOD
                 0.1000000E+02  IN YEARS

-------------------------------------------------------------------------------------------------------------------

                                                   MASS BALANCE

                CUMULATIVE
                  VOLUMES                                                                        RATES
 ----------------------------------------                                      ----------------------------------------
       SOURCES            DISCHARGES                                                  SOURCES            DISCHARGES
    -------------       -------------                                             -------------       -------------
    0.1755693E+09       0.2137128E+10       SPECIFIED-HEAD BOUNDARIES              0.0000000E+00       0.2700960E+01
                        0.0000000E+00          EVAPOTRANSPIRATION                                      0.0000000E+00
    0.9460800E+08       0.2094684E+10               PUMPAGE                        0.2000000E+00       0.2000000E+00
    0.0000000E+00                                   RECHARGE                       0.0000000E+00
    0.3777311E+10       0.2023794E+09     INDUCED FLUX FROM/TO RIVERS              0.3000000E+01       0.0000000E+00
    0.3966905E+09                                   STORAGE                       -0.2990290E+00
    0.4434179E+10       0.4434192E+10                 SUM                          0.2900971E+01       0.2900960E+01

-------------------------------------------------------------------------------------------------------------------

               -0.1298126E+05                NET (SOURCE - DISCHARGE)                      0.1061683E-04
               -0.2927546E-03                   PERCENT DIFFERENCE

-------------------------------------------------------------------------------------------------------------------

    0.0000000E+00       0.0000000E+00          SPECIFIED-HEAD NODE FLUX            0.0000000E+00       0.0000000E+00

-------------------------------------------------------------------------------------------------------------------
```

```
RIVER FLOW/DISCHARGE DATA:  34 RIVER NODES DEFINED FOR   5 RIVERS.
                                                NODE   ROW   COL LAYER  RATE TO GW  RATE DOWNSTREAM
                                                ----- ----- ----- ----- ----------- ---------------

RIVER REACH   1 HAS   10 NODES.
                                                   1     8    19     2  0.3000E+00  0.7000E+00
                                                   2     9    18     2  0.3000E+00  0.4000E+00
                                                   3    10    17     2  0.3000E+00  0.1000E+00
                                                   4    11    16     2  0.1000E+00  0.0000E+00
                                                   5    12    15     2  0.0000E+00  0.0000E+00
                                                   6    12    14     2  0.0000E+00  0.0000E+00
                                                   7    12    13     2  0.0000E+00  0.0000E+00
                                                   8    13    12     2  0.0000E+00  0.0000E+00
                                                   9    13    11     2  0.0000E+00  0.0000E+00
                                                  10    13    10     2  0.0000E+00  0.0000E+00
RIVER REACH   2 HAS    6 NODES.

                                                  11    19    12     2  0.3114E+00  0.1689E+01
                                                  12    18    12     2  0.3715E+00  0.1317E+01
                                                  13    17    12     2  0.3557E+00  0.9613E+00
                                                  14    16    12     2  0.3241E+00  0.6372E+00
                                                  15    15    11     2  0.2935E+00  0.3437E+00
                                                  16    14    10     2  0.2651E+00  0.7859E-01
RIVER REACH   3 HAS    7 NODES.

                                                  17    13     9     2  0.7859E-01  0.0000E+00
                                                  18    13     8     2  0.0000E+00  0.0000E+00
                                                  19    13     7     2  0.0000E+00  0.0000E+00
                                                  20    12     6     2  0.0000E+00  0.0000E+00
                                                  21    12     5     0  0.0000E+00  0.0000E+00
                                                  22    11     4     2  0.0000E+00  0.0000E+00
                                                  23    11     3     2  0.0000E+00  0.0000E+00
RIVER REACH   4 HAS    6 NODES.

                                                  24    13    12     0  0.0000E+00  0.0000E+00
                                                  25    13    11     0  0.0000E+00  0.0000E+00
                                                  26    13    10     0  0.0000E+00  0.0000E+00
                                                  27    14    12     0  0.0000E+00  0.0000E+00
                                                  28    14    11     0  0.0000E+00  0.0000E+00
                                                  29    14    10     0  0.0000E+00  0.0000E+00
RIVER REACH   5 HAS    5 NODES.

                                                  30    13     9     0  0.0000E+00  0.0000E+00
                                                  31    13     8     0  0.0000E+00  0.0000E+00
                                                  32    13     7     0  0.0000E+00  0.0000E+00
                                                  33    11     4     0  0.0000E+00  0.0000E+00
                                                  34    11     3     0  0.0000E+00  0.0000E+00

REMAINING DISCHARGE IN STREAM REACHES:

RIVER REACH  DISCHARGE
-----------  -----------
     1       0.0000E+00
     2       0.7859E-01
     3       0.0000E+00
     4       0.0000E+00
     5       0.0000E+00

--------------------------------------------------------------------------------------------------
```

REFERENCES

Kentron International, Inc., 1980, Revised three-dimensional water resources flow model, prepared for U.S. Geological Survey, Water Resource Division, Albuquerque, New Mexico, 39 p.

Posson, D. R., Hearne, G. A., Tracy, J. V., and Frenzel, P. F., 1980, A computer program for simulating geohydrologic systems in three dimensions: U.S. Geological Survey Open-File Report 80-421, 795 p.

Trescott, P. C., 1975, Documentation of finite-difference model for simulation of three-dimensional ground-water flow: U.S. Geological Survey Open-File Report 75-438, 108 p.

Trescott, P. C., and Larson, S. P., 1976, Supplement to Open-File Report 75-438, Documentation of finite-difference model for simulation of three-dimensional ground-water flow: U.S. Geological Survey Open-File Report 76-591, 21 p.

Trescott, P. C., Pinder, G. F., and Larson, S. P., 1976, Finite-difference model for aquifer simulation in two dimensions with results of numerical experiments: U.S. Geological Survey Techniques of Water-Resources Investigations, Chapter C1, Book 7, 116 p.

Wilkins, D. W., Scott, W. B., and Kaehler, C. A., 1980, Planning report for the Southwest Alluvial Basins (east) Regional Aquifer System Analysis, Parts of Colorado, New Mexico, and Texas: U.S. Geological Survey Open-File Report 80-564, 39 p.