DOCUMENTATION OF A COMPUTER PROGRAM TO SIMULATE STREAM-AQUIFER RELATIONS USING A MODULAR, FINITE-DIFFERENCE, GROUND-WATER FLOW MODEL

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PREFACE

This report presents a computer program for the simulation of stream-aquifer relations. A formal release of this report will be available in the future as a chapter in Techniques of Water Resources Investigations of the U.S. Geological Survey. The program documented in this report is designed for incorporation into the modular finite-difference ground-water flow model developed by the U.S. Geological Survey. The performance of this computer program has been tested in models of both hypothetical and actual ground-water flow systems. Future applications, however, may reveal errors that were not detected in the test simulations. Prior to the formal release of this report, users are requested to notify the originating office of any errors found in the report or in the computer program. Updates may occasionally be made to both the report and computer program. Users who wish to receive future updates, if any, may send a request to:

U.S. Geological Survey
Federal Bldg., Room 224
705 North Plaza Street
Carson City, Nevada 89701

Copies of the computer program and test data sets are available on tape or diskette at the cost of processing. The copies may be obtained from:

U.S. Geological Survey
WATSTORE Program Office
437 National Center
Reston, Virginia 22092
Telephone: (703) 648-5695

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CONVERSION FACTORS AND ABBREVIATIONS

"Inch-pound" units of measure used in this report may be converted to metric (International System) units by using the following factors.

Multiply inch-pound unit	By	To obtain metric unit
inch (in.)	2.54	centimeter (cm)
foot (ft)	0.3048	meter (m)
foot per second (ft/s)	0.3048	meter per second (m/s)
foot per day (ft/d)	0.3048	meter per day (m/d)
square foot per second (ft^2/s)	0.09290	square meter per second (m^2/s)
square foot per day (ft^2/d)	0.09290	square meter per day (m^2/d)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
cubic foot per day (ft^3/d)	0.02832	cubic meter per day (m^3/d)

ALTITUDE DATUM

Sea level: In this report, "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929)-- a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called "Sea Level Datum of 1929."

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ABSTRACT

Computer models are widely used to simulate ground-water flow for evaluating and managing the ground-water resources of many aquifers, but few are designed to also account for surface flow in streams. A computer program was written for use in the U.S. Geological Survey modular finite-difference ground-water flow model to account for the amount of flow in streams and to simulate the interaction between surface streams and ground water. The new program is called the Streamflow-Routing Package.

The Streamflow-Routing Package is not a true surface-water flow model but rather is an accounting program that tracks the flow in one or more streams which interact with ground water. The program limits the amount of ground-water recharge to the available streamflow. It permits two or more streams to merge into one with flow in the merged stream equal to the sum of the tributary flows. The program also permits diversions from streams.

Streams are divided into segments and reaches. Each reach corresponds to individual cells in the finite-difference grid used to simulate ground-water flow. A segment consists of a group of reaches connected in downstream order. Leakage is calculated for each reach on the basis of the head difference between the stream and aquifer and a conductance term. It is subtracted or added to the amount of streamflow into the reach. The stage in each reach can be computed using the Manning formula under the assumption of a rectangular stream channel.

The amount of leakage in each reach (either into or out of the aquifer) is incorporated into the ground-water flow model by adding terms to the finite-difference equations. Recharge to the aquifer in a reach ceases when all the streamflow in upstream reaches has leaked into the aquifer and the stream is dry. A stream is permitted to flow again in downstream reaches if the head in the aquifer is above the elevation of the streambed.

Results from the program have been compared to results from two analytical solutions. One assumes time varying areal recharge to the aquifer and discharge only to a stream and the other assumes recharge to the aquifer from a change in stream stage. Results from the program reasonably duplicated the analytical solutions.

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The ground-water flow model with the Streamflow-Routing Package has an advantage over the analytical solution in simulating the interaction between aquifer and stream because it can be used to simulate complex systems that cannot be readily solved analytically.

The Streamflow-Routing Package does not include a time function for streamflow but rather streamflow entering the modeled area is assumed to be instantly available to downstream reaches during each time period. This assumption is generally reasonable because of the relatively slow rate of ground-water flow. Another assumption is that leakage between streams and aquifers is instantaneous. This assumption may not be reasonable if the streams and aquifers are separated by a thick unsaturated zone.

Documentation of the Streamflow-Routing Package includes data input instructions; flow charts, narratives, and listings of the computer program for each of four modules; and input data sets and printed results for two test problems, and one example problem.

INTRODUCTION

Computer models that simulate ground-water flow are widely used to evaluate and manage ground-water resources in many areas of the Nation. Early models were somewhat limited in the types of processes that could be simulated without making major changes in the program codes. McDonald and Harbaugh (1988) developed a computer program that simulates three-dimensional ground-water flow and includes the effects of many processes such as areal recharge, rivers, drains, evapotranspiration, and pumpage. Their program is designed to allow for additional capabilities to be easily incorporated into it. The program is divided into a main program and a series of independent subprograms called packages. A package is a group of subroutines, called modules, that deals with a single aspect of the simulation. For example, the River Package simulates leakage between rivers and aquifer. Changes to a package or an addition of a new package does not require major changes to other packages in McDonald and Harbaugh's program.

The package that simulates the effects of rivers on an aquifer only accounts for leakage to or from the rivers. It does not track the amount of flow in the rivers nor does it permit rivers to go dry during a given period of simulation. In many areas, particularly in the western United States, streams become dry as they flow across large ground-water basins. In addition, water commonly is diverted from rivers or streams through canals or ditches to irrigated fields. The effects of ephemeral streams and irrigation canals can now be simulated with a new package. The package was developed to route streamflows in one or more streams across a ground-water basin; when flow in a stream ceases, the simulation of recharge from the stream to the aquifer system also ceases.

This report documents: (1) the basic concepts of the Streamflow-Routing Package, (2) the results of three test simulations, (3) the data input instructions needed to use the program, (4) the computer program, including a narrative, flow chart, program listing and a description of variables for each module, and (5) the input data sets used for the three test simulations and selected parts of the printed results.

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CONCEPTUALIZATION OF ROUTING STREAMFLOWS

The Streamflow-Routing Package is a modification of the River Package described by McDonald and Harbaugh (1988, p. 6-1 through 6-30) and is designed to be incorporated into their program. The new package is designed to route flow through one or more rivers, streams, canals, or ditches (all of which are hereafter referred to as streams, for convenience) in addition to computing leakage between the streams and the aquifer system.

Numbering and Ordering of Streams

A brief description of the model developed by McDonald and Harbaugh (1988) is necessary prior to describing the numbering and ordering of streams. The program of McDonald and Harbaugh solves the three-dimensional ground-water flow equation using finite-difference approximations (p. 2-1 through 2-35). The finite-difference procedure requires that the aquifer be divided into blocks called cells, which have dimensions x, y, and z. The aquifer properties in each cell are assumed uniform. The unknown head in each cell is calculated at a point or node at the center of the cell. The head is calculated by iterating through the finite-difference equations for all nodes until the maximum head change in any cell between the previous iteration and the current iteration is less than a value specified by the user. Once this criterion is met, the program advances to a new time step and the process of computing heads at each node is repeated.

Streams superimposed on the aquifer are divided into reaches and segments. A segment is a stream or diversion in which streamflow from surface sources are added at the beginning of the segment or subtracted (in the case of a diversion) at the end of a segment. A reach is the part of a segment that corresponds to an individual cell in the finite-difference grid used to simulate ground-water flow in an aquifer. A segment may consist of one or more reaches. Segments are numbered sequentially from the farthest upstream segment to the last downstream segment as are reaches within each segment. Both must also be read into the program in sequential order. The use of segments in the conceptualization of routing streamflows makes the accounting of flows where streams merge to form one, or where diversions subtract flow from a stream, easier to program. Reaches, however, form the basis for the calculation of leakage between surface water and ground water.

An example of a finite-difference grid of a hypothetical aquifer connected to streams is shown in figure 1a. In this example, the locations of cells representing the aquifer are described in terms of rows and columns. Thus, cell (1,3) is the cell located in row 1, column 3. The streams are divided into segments and reaches. Segment 1 has two reaches and begins in cell (1,3) and ends in cell (2,3) where some flow is diverted into segment 2. The remaining flow from segment 1 goes to segment 3, which has 4 reaches. Segments 2 and 4 join in cell (5,3) to form segment 5. Segments 3, 5, and 6 join in cell (5,4) to form segment 7. Two small parts of streams in segments 3 and 6 are not included in the numbering scheme because they only cross the corners of cells (2,4) and (3,5).

A.

B.

ROWS

COLUMNS

Not to scale

EXPLANATION

→ STREAM CHANNEL OR DIVERSION--Arrow indicates direction of flow

②● STREAM SEGMENT--Dots indicate section of stream used to define a segment. Enclosed number is the segment number. Open number is the reach number within a segment

▨ SECTION OF STREAM CHANNEL OR DIVERSION--Shows sections of streams or diversions not included in model simulation

Canal

Figure 1.--Example numbering systems of streams and diversions for the simulation of stream-aquifer relations with the finite-difference ground-water flow model by McDonald and Harbaugh (1988). A, one method of numbering streams and diversions. B, an alternative method of numbering streams and diversions.

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A diversion from one segment can later become tributary to another segment, which is the case for segment 2 in figure 1a. Also, more than one reach in different segments can be assigned to the same model cell. For example, reach 2 in segment 5; reach 4 in segment 3; reach 5 in segment 6, and reach 1 in segment 7 are all located in cell (5,4). Leakage to or from the aquifer from all these reaches is the accumulated sum of all the leakage, however, the leakage between each reach and the cell is calculated at the cell node (located in the center of the cell). Thus, only the head at the cell node is used to calculate leakage for each reach.

An alternative numbering scheme is shown in figure 1b whereby only one reach and segment is assigned to a cell. In the example, segment 2 (the diversion canal) begins in cell (3,3) and segment 3 begins in cell (3,4). Segment 5 has only one reach, located in cell (5,3), but it consists of parts of three streams. This scheme results in assigning fewer reaches but causes the combining of flows prior to the confluence of streams and the subtraction of flows after the diversion.

Streamflow Accounting

Streamflow is accounted for by specifying flow for the first reach in each segment that enters the modeled area, and then computing streamflow to adjacent downstream reaches in each segment as equal to inflow in the upstream reach plus or minus leakage from or to the aquifer in the upstream reach. The accounting scheme used assumes that streamflow entering the modeled layer is instantly available to downstream reaches. This assumption is generally reasonable because of the relatively slow rates of ground-water flow.

Streamflow into a segment that is formed from tributary streams is computed by adding the outflows from the last reach in each of the specified tributary segments. If a segment is a diversion, then the specified flow into the first reach of the segment is subtracted from flow in the main stream. However, if the specified flow of the diversion is greater than the flow out of the segment from which flow is to be diverted, then no flow is diverted from that segment.

Reaches in a segment are permitted to go dry whenever downward leakage to the aquifer exceeds stream inflow into the reach. The downstream reaches also go dry (streamflow into the downstream reaches is zero) and leakage into the aquifer is not permitted. Upward leakage (from the aquifer) is permitted even when there is no streamflow in a reach. This happens when the head in the aquifer exceeds the top of the streambed in a dry reach. Flow in the stream resumes and downward leakage back into the aquifer can be simulated in downstream reaches.

5

Stream stage (head)

Length of reach (L)

Water table

Land surface

Hydraulic conductiv-
ity of streambed (K)

←(W)→
Width of stream

(M) Thickness of
streambed

Aquifer

Not to scale
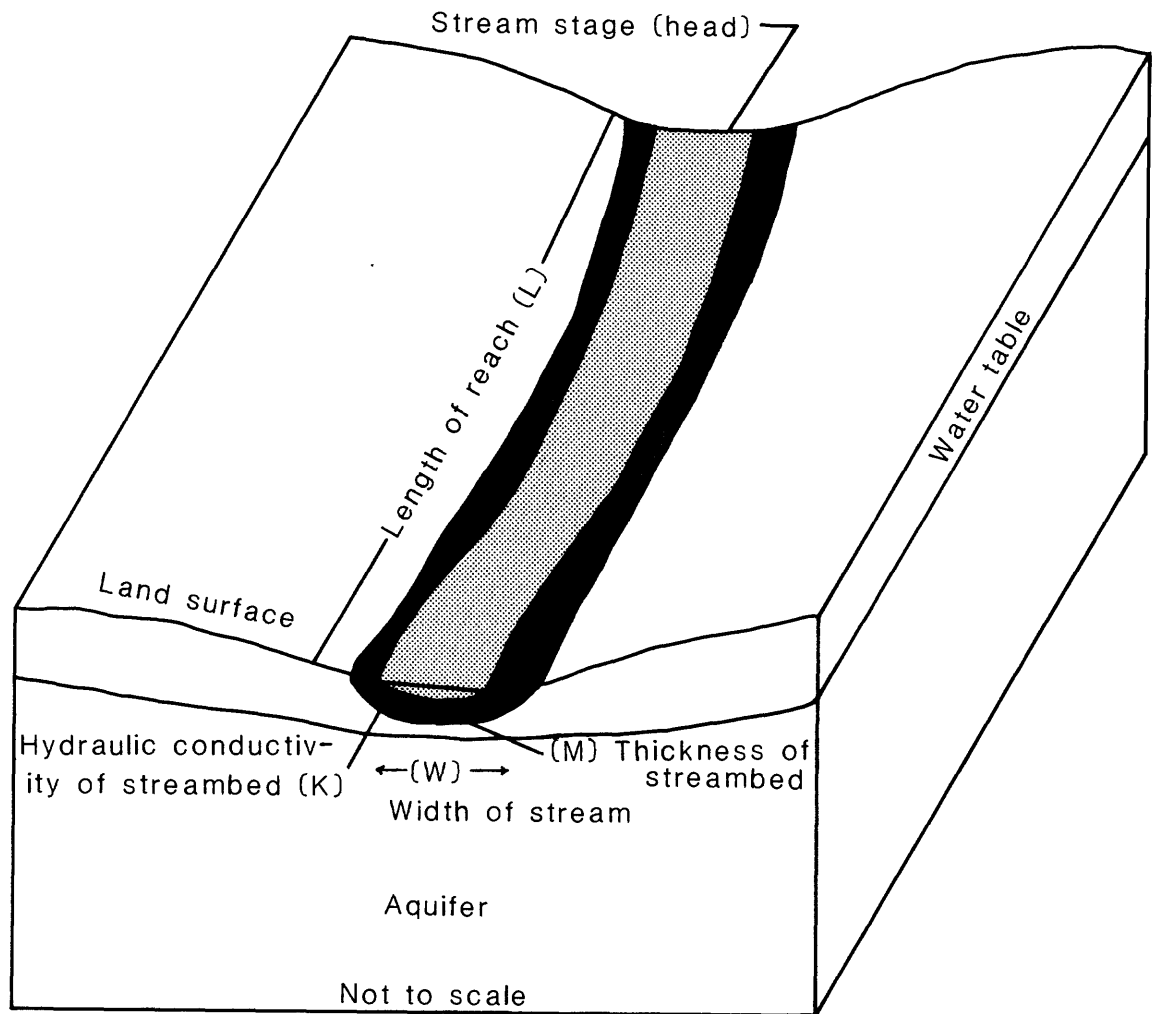
Conductance of streambed (CSTR)

$$CSTR = \frac{KLW}{M}$$

Figure 2.--Diagram showing part of an aquifer with a stream over it depicting
how conductance of the streambed is calculated for a reach.

Computing Flow Between Stream and Aquifer

Leakage to or from a stream reach is computed by Darcy's Law as follows:

$$Q_l = CSTR \ (H_s - H_a) \tag{1}$$

where Q_l = leakage to or from the aquifer through the streambed, (L^3/T);

H_s = head in the stream, (L);

H_a = head in aquifer side of streambed, (L); and

CSTR = conductance of the streambed (L^2/T), which is the hydraulic conductivity of the streambed times the product of the width of the stream and its length divided by the thickness of the streambed.

A sketch of the properties used in the calculation of stream leakage to or from the aquifer is shown in figure 2. The stage in the stream is for the center of the reach. The head in the aquifer side of the streambed depends upon whether the earth materials beneath the stream are saturated or not. If the materials are saturated, then the head in the aquifer side of the streambed is equal to the head in the model cell beneath the stream reach. If materials are unsaturated, then the head in the aquifer beneath the streambed is equal to the elevation of the bottom of the streambed. The relation between stream leakage and head in the model cell is shown in figure 3. For more detailed information regarding this relation, the reader is referred to McDonald and Harbaugh (1988, p. 6-1 through 6-30). If leakage through the streambed to the aquifer in a stream reach is greater than the amount of streamflow that enters the reach, then the leakage is set equal to the streamflow that enters the reach and flow out of the reach is zero. Inflow into the adjacent downstream reach is also zero.

The terms that represent leakage to or from the stream reaches are added to the finite-difference equations at the start of each iteration in the same manner as in the River Package described by McDonald and Harbaugh (1988, p. 6-12). If streamflow is zero in a reach and the head in the model cell is less than the top of the streambed, then no leakage is computed for that reach. The choice as to which terms to add to the finite-difference equations is made by comparing the most recent value of the head in the model cell to the elevation of the bottom of the streambed; or if flow in the stream reach is zero, to the top of the streambed. These comparisons are made at the start of each iteration, meaning that the most current value of head in the model cell used to calculate leakage between stream reaches and the aquifer is from the previous iteration.
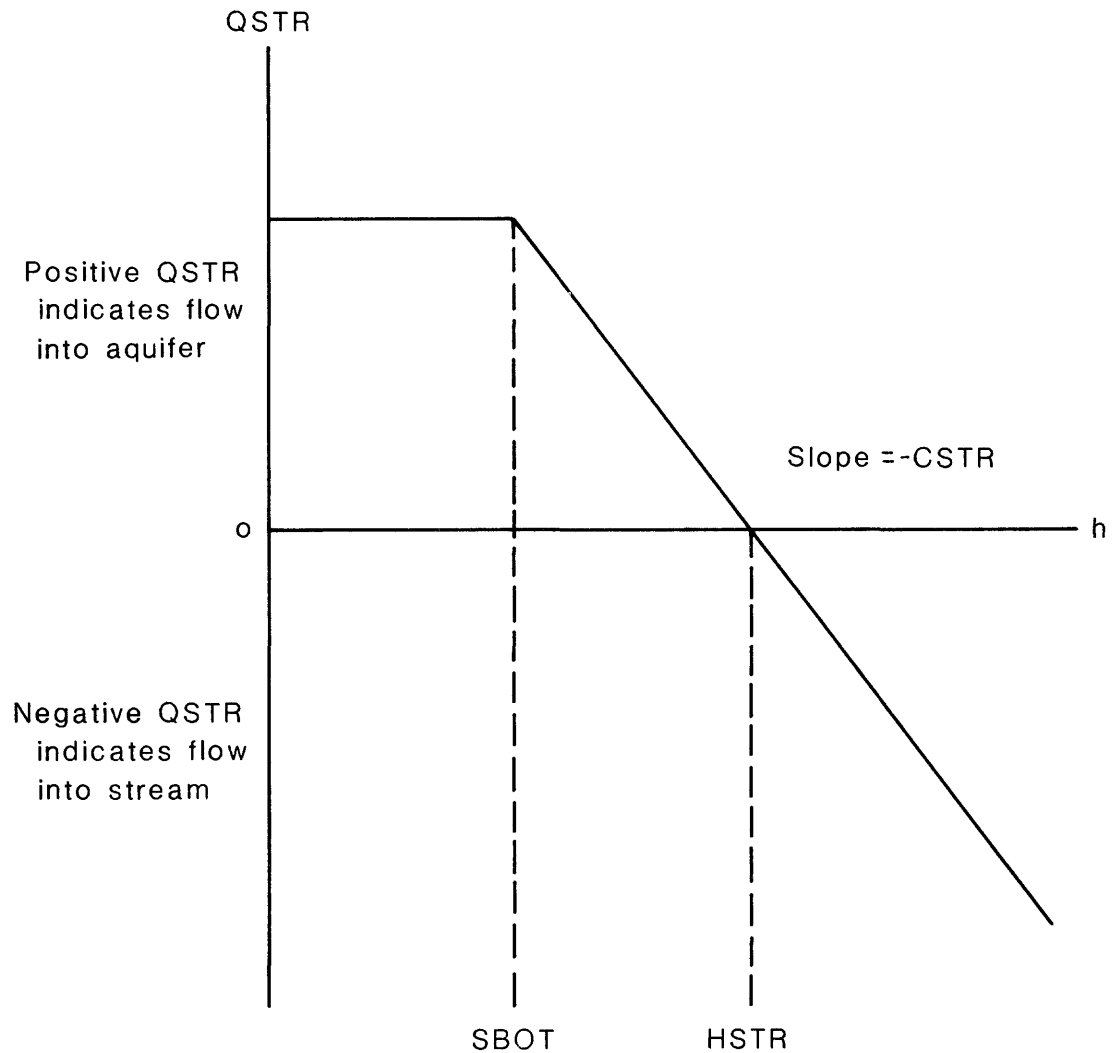
Figure 3.--Leakage, QTSR, through a streambed into an aquifer as a function of head, h, in a model cell where SBOT is the streambed bottom and HSTR is the stream stage. Slope is dependent on streambed conductance, CSTR. Modified from McDonald and Harbaugh (1988, p. 6-9).

Computing Stream Stage in Reaches

An option in the package is available that computes the stream stage in each reach. If the option is used, the stream stage is computed assuming incompressible steady flow in the stream at constant depth and using the Manning formula as described by Ozbilgin and Dickerman (1984, p. 3, eq. 1) as:

$$Q = \frac{C}{n}(A\ R^{2/3}\ S^{1/2}), \qquad (2)$$

where Q = stream discharge, (L^3/T);

  n = Manning's roughness coefficient, dimensionless;

  A = cross-sectional area of the stream, (L^2);

  R = hydraulic radius, (L);

  S = slope of the stream channel, (L/L); and

  C = a constant, $(L^{1/3}/T)$, which is 1.486 for units of cubic feet per second or 1.0 for cubic meters per second.

The Manning formula, in particular, the units of (C/n), is discussed by Chow (1959, p. 98-101). The cross-sectional area and the hydraulic radius for a rectangular channel are:

$$A = wd\ , \text{ and} \qquad (3)$$

$$R = \frac{wd}{w + 2d} \qquad (4)$$

where d = depth of the water in the stream, (L); and

  w = width of the channel, (L).

Substituting these equations into equation 2 and assuming that the depths of the streams are much less than the width, Ozbilgin and Dickerman (1984, p. 4) derived the following equation that computes stream depth:

$$d = \left[\frac{Qn}{CwS^{1/2}}\right]^{3/5} \qquad (5)$$

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This is the equation used to approximate the stream stage in each reach in the Streamflow-Routing Package.

A brief discussion of Manning's roughness coefficient is presented by White (1979, p. 602-607). White (p. 605) presented estimates of Manning's roughness coefficient for a variety of stream channels. The estimates are listed in table 1.

Streamflow estimates from the Manning formula are accurate in an intermediate range of roughness coefficients (White, 1979, p. 602-607), but for deep, smooth channels and shallow, rough channels the estimates of flow may be unrealistic. Roughness coefficients can be estimated from actual measurements of stream depth and discharge. However, if field data are not available, values can be estimated from table 1.

TABLE 1.--*Experimental values of Manning's roughness coefficient*
(White, 1979, p. 605)

Description of channel	Manning's roughness coefficient (n)
Excavated earth channels:	
Clean	0.022 ± 0.004
Gravelly	0.025 ± 0.005
Weedy	0.030 ± 0.005
Stony, cobbles	0.035 ± 0.010
Natural channels:	
Clean and straight	0.030 ± 0.005
Sluggish, deep pools	0.040 ± 0.010
Major rivers	0.035 ± 0.010
Floodplains:	
Pasture, farmland	0.035 ± 0.010
Light brush	0.050 ± 0.020
Heavy brush	0.075 ± 0.025
Trees	0.150 ± 0.050

The stream stage in each reach is computed prior to calculating leakage to or from the aquifer. For the first iteration, the stage for each reach is calculated using the specified inflow into a stream segment. If no streamflow is specified into a segment, the stage for all reaches in the segment will equal the top of the streambed. Leakage terms are then calculated on the basis of the computed stream stage, streambed conductance, and the initial (starting) head in each corresponding model cell. These terms are added to the finite-difference equations used to calculate a new

head for each model cell. The process continues, except in the following iterations, leakage calculated in the previous iteration is added or subtracted from streamflow prior to calculating a new stream stage, and new leakage terms are computed on the basis of the head in the corresponding model cell calculated from the previous iteration.

Assumptions and Limitations

The Streamflow-Routing Package does not include a time function for routing flows specified for the first reach in each segment that enters the modeled area to downstream reaches. The accounting scheme used assumes that streamflow entering the modeled area is instantly available in downstream reaches for each specified period in the model simulation. (The specified period is referred to as a stress period by McDonald and Harbaugh, 1988, p. 1-5). This assumption is generally valid because of the relatively slow rate of ground-water flow and because stress periods used in model simulations are commonly months or years, whereas changes in streamflow along a course of a stream are usually in days.
   Stream stage for a reach can be calculated using the Manning formula and assuming a rectangular channel with a stream width much greater than depth. The assumption of a rectangular channel with width much greater than depth is generally valid but may not be appropriate for all streams. Thus, using this method to calculate a stream stage may not be valid for all cases.
   The numerical scheme where information from the pervious iteration is used to determine stream stage, streamflow, and the leakage terms in the finite-difference equations can, in some cases, cause instability in the iterative solution process. Such instability may be more prominent when stream leakage is a dominant part of the simulation.
   Streambed conductance values used to calculate leakage between a reach and a model cell are specified a constant for each stress period. Widths of a stream channel usually vary depending on the flow and stage in the stream which may result in varying streambed conductance values. In the package presented herein, changes in the streambed conductances due to changing streamflows must be computed separately from the model and then added at the beginning of each stress period.
   Another limitation of the model is that leakage from the stream to the aquifer is assumed to be instantaneous, which is reasonable where the thickness of the unsaturated zone between a stream and aquifer is not great. The assumption may be unreasonable when the thickness of the unsaturated zone is large, because of the time lag between stream infiltration and recharge to the aquifer. In addition, the stream infiltration rate may be greater than the amount of recharge to the aquifer because some of the infiltrated water may be used to replace soil moisture and(or) be used by plants adjacent to the stream.
   The Streamflow-Routing Package can be used to simulate the leakage between streams and aquifers. But the user must consider the limitations associated with the package when using it as the package may not be appropriate for all cases. The accuracy of the model results will, to a large extent, be dependent on the size of the model cells, the time

intervals used in the simulations, and the closure criteria for completing the iteration cycle in the modular model (McDonald and Harbaugh, 1988, p. 2-20 through 2-25).

RESULTS OF TEST SIMULATIONS

The package is designed primarily to simulate vertical leakage from partially penetrating streams with a distinct streambed and associated hydraulic conductivity. With some slight changes in the concept of calculating streambed conductance values, the program can be used to simulate a fully penetrating stream. This was done in comparing simulation results to two analytical solutions, which assume a fully penetrating stream. The comparisons were done to verify that the program works correctly.

For the first test, results from the Streamflow-Routing Package were compared to results from an analytical solution developed by Oakes and Wilkinson (1972). An idealized aquifer with a river flowing through the middle was chosen and is shown in figure 4. The width of the aquifer perpendicular to the river was 4,000 ft on each side, while the length parallel to the river was 13,000 ft. Assumptions used in both the analytical solution and the model simulation include:

1. The lateral boundaries of the aquifer are impermeable (no flow is allowed).

2. The rocks beneath the aquifer are impermeable.

3. The river penetrates the entire depth of the aquifer and has vertical banks.

4. The river is not separated from the aquifer by any confining material.

5. The transmissivity and storage coefficient are constant throughout the aquifer and remain constant in time.

6. The aquifer is unconfined and Darcy's Law is valid.

7. The flow of ground water is horizontal.

8. The water level in the river is constant along its length and with time.

9. The infiltration of recharge to the aquifer is instantaneous (no delay between the time precipitation infiltrates the surface until it reaches the water table).

10. The discharge from the aquifer is only to the river.

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COLUMNS

1   5   10   15   20   25   30   35   39

ROWS (Length of each row, 1,000 feet)

1

2

3

4   ↙River

5

6

7   Well●

8

9

10

11

12

13

13,000 feet

├──────────── 8,000 feet ────────────┤

Columns 1 and 39 are 300 feet in length
Columns 2-38 are 200 feet in length
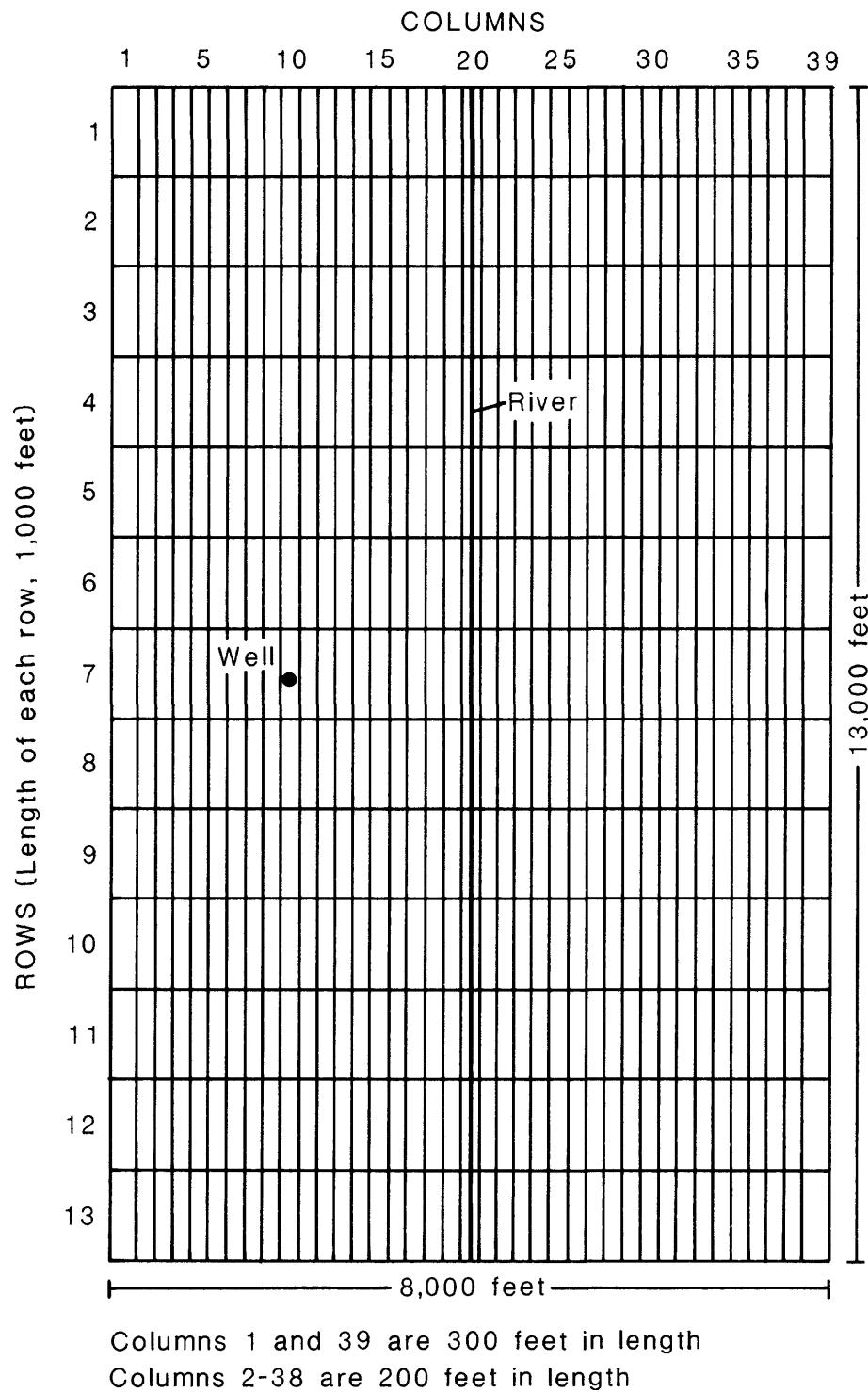
Figure 4.--Sketch showing an idealized aquifer with
model grid and associated river and well.

Transmissivity of the aquifer used for both the analytical solution and in the model simulation was 3,200 ft^2/d (0.037 ft^2/s). The storage efficient was 0.20. Because the river is assumed fully penetrating and the aquifer is not separated from the river by any confining material, the streambed conductance value was assumed equal to the transmissivity of the aquifer (in this example, the width of the river is assumed equal to the depth of the aquifer) times the length of the river in each cell (1,000 ft) divided by an assumed 1-foot thickness of the riverbed. Actually, any large streambed conductance value can be used as long as the head value in the model cell (node) that corresponds to the river remains constant during the simulation. Results of varying the streambed conductance value indicates that for this problem, streambed conductances greater than 10 ft^2/d produce nearly the same results. The Streamflow-Routing Package is not really needed to simulate this condition, as the stream could have been represented using constant heads in model cells representing the stream but the simulation was done to determine if the package correctly accumulates flow from the aquifer into the stream.

Annual recharge to the aquifer was 1.5 ft and it was applied evenly over the aquifer. However, the daily recharge rate varied according to a sinusoidal distribution for the first 180 days, while no recharge was allowed for the following 180 days (fig. 5). The sinusoidal distribution was divided into 15-day intervals for the model simulation and the rate for the middle of each interval was used as a constant. The distribution used in the simulation is also shown in figure 5.

A total of six 360-day infiltration periods were used in the simulation. The first five periods were done to allow the model to reach a stable yearly cycle because the initial starting water level for each model cell was not known. Results of the model simulation from the sixth infiltration period are compared to the results from the analytical solution for an observation well 2,000 ft from the river (fig. 6). The location of the well is shown in figure 4. The same results were obtained using the River Package in the modular model (McDonald and Harbaugh, 1988). The data set used in the model simulation with the Streamflow-Routing Package and the results for the last 360-day infiltration period are listed in Appendix I.

The water level computed with the model closely matches the water level calculated from the analytical solution (fig. 6a). Streamflow computed with the model (fig. 6b) is slightly less during the period of increasing streamflow (0-100 days) and slightly more than streamflow calculated from the analytical solution immediately following peak streamflows (120-180 days).

The slight difference in flows between the simulation results and the analytical solution most likely is caused either by the size of the model cells in the direction of ground-water flow (columns) or by the length of the stress periods used to simulate the changes in recharge. Increasing the number of columns (decreasing the size of model columns) and(or) reducing the length of the stress periods probably would result in a closer approximation of the computed flow to the flow calculated with the analytical solution.

14
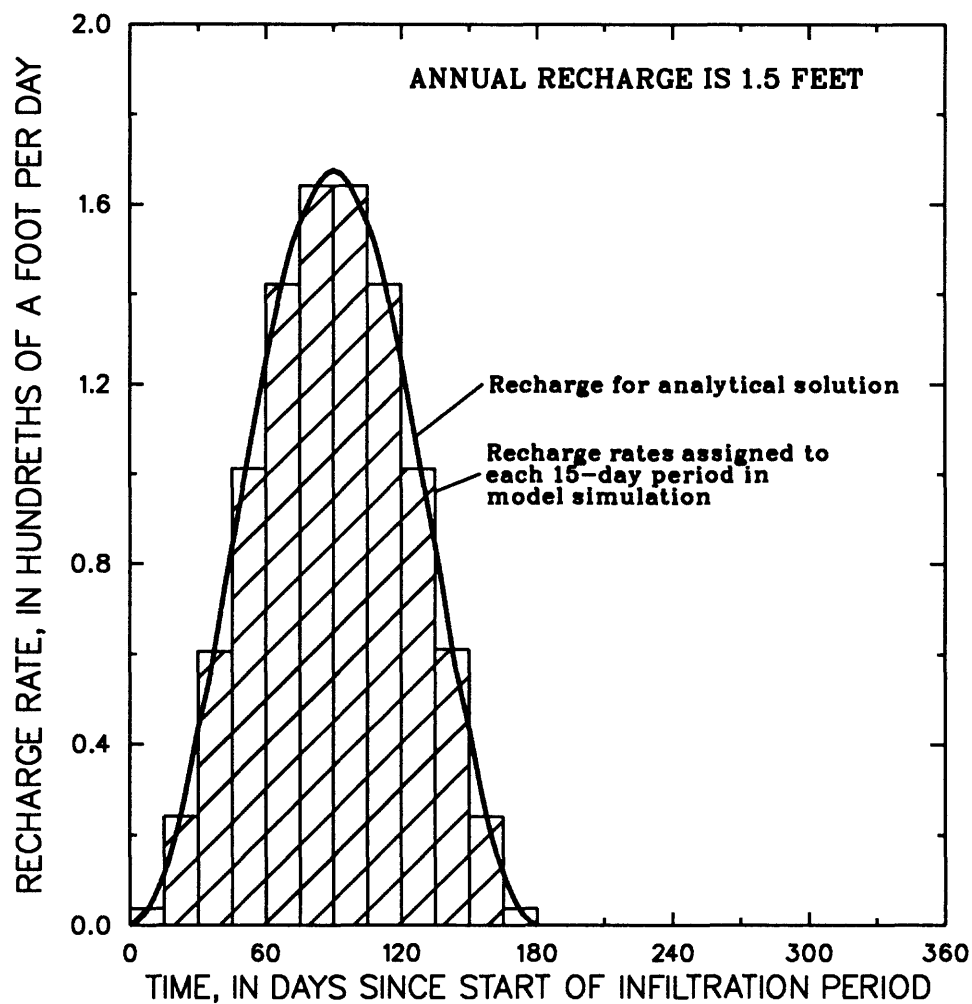
Figure 5.--Distribution of recharge used for analytical solution and how it was divided into time intervals for the simulation of test problem 1.

A.

B.

TIME, IN DAYS SINCE START OF INFILTRATION PERIOD
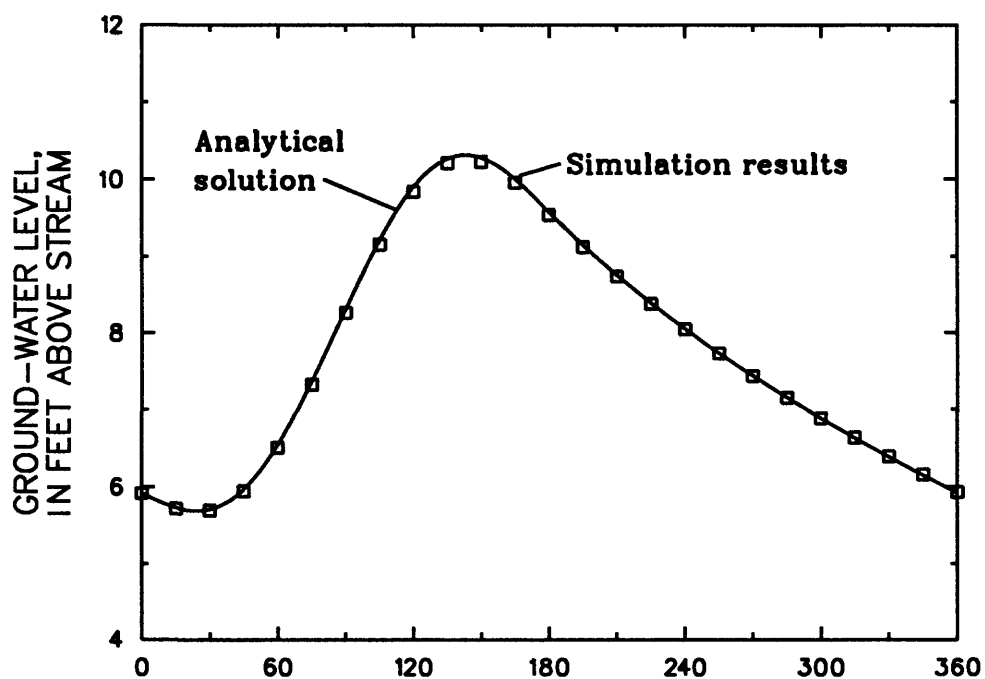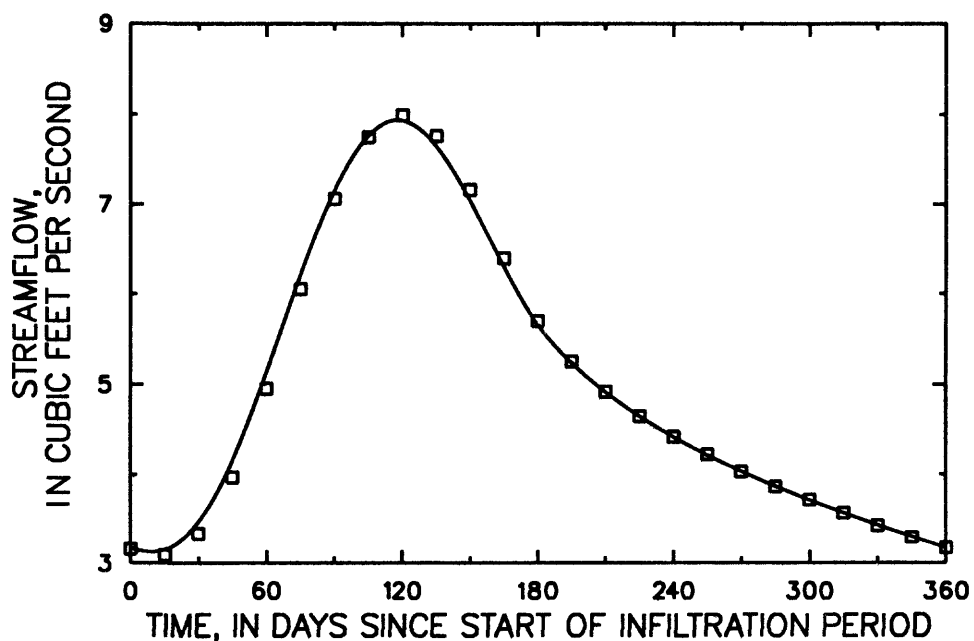
Figure 6.--Comparison of simulation results for test problem
1 to analytical solution developed by Oakes and Wilkinson
(1972). A, Ground-water levels at a well 2,000 feet
from river; B, Base flows for the river summed over its
modeled length.

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For the second test, the function that computes the head in the stream as well as simulating changes in flows to and from the aquifer was compared to an analytical solution developed by Cooper and Rorabaugh (1963). The same model grid used in the first test (fig. 4) was used in this test. The assumptions used in the previous test are the same except for assumptions 8-10, which are replaced with the following assumptions:

1. The recharge to the aquifer is only from the river as river stage increases with time.

2. The discharge from the aquifer is also only to the river as river stage decreases with time.

The aquifer properties used in this test were the same as those used in the first test. The analytical solution used from Cooper and Rorabaugh (1963, p. 355-358) is applicable for the case where the lateral boundary is at infinity (referred by Cooper and Rorabaugh as semi-infinite). The impermeable boundary assigned at 4,000 ft for this test is of sufficient distance from the river as not to interfere with the results.

A flood in the river was simulated for a 30-day period. The procedure used to calculate the distribution of streamflow for the 30-day period and for 60 days following the flood was first to calculate a distribution of river stage using equation 71 in Cooper and Rorabaugh (1963, p. 355), assuming a maximum flood stage of 4 ft above the initial river stage. The streamflow distribution shown in figure 7 then was calculated by rearranging equation 5 and solving for streamflow. The streamflow distribution was calculated from the river stage distribution, a river width of 100 ft, a roughness coefficient of 0.02377, a slope of 0.0001, and a constant (C in equation 5) of 1.486 (used when flow is in cubic feet per second). The input for this test simulation and selected parts of the printed results are included in Appendix II.

Streamflow for the first 30 days was divided into 1-day periods for simulation (fig. 7). Simulation results of computed river stage are shown in figure 8 as are the results from manually calculating river stage using equation 71 of Cooper and Rorabaugh (1963, p. 355). The simulation results are the same as the manually calculated values, indicating the equation that calculates stream stage has been correctly written in the computer program. Leakage computed between the river and aquifer in the simulation also closely approximated the analytical solution for a semi-infinite aquifer (fig. 9). Results of varying both the number of columns and the length of stress periods used to simulate the flood wave indicate that both the number of columns and the length of the time step are important in exactly duplicating the analytical solution.

The ground-water flow model with the Streamflow-Routing Package has an advantage over analytical solutions because it can be used to simulate complex systems. The example of a stream system shown in figure 1a is used to illustrate most of the features of the package. The example assumes an aquifer 6,000 ft wide by 6,000 ft long divided into six equally spaced rows and columns. The transmissivity of the aquifer is 0.08 ft^2/s (6,900 ft^2/d). Recharge to the aquifer occurs only from stream leakage as does discharge from the aquifer. Land-surface altitude varies over the modeled area as shown in figure 10.
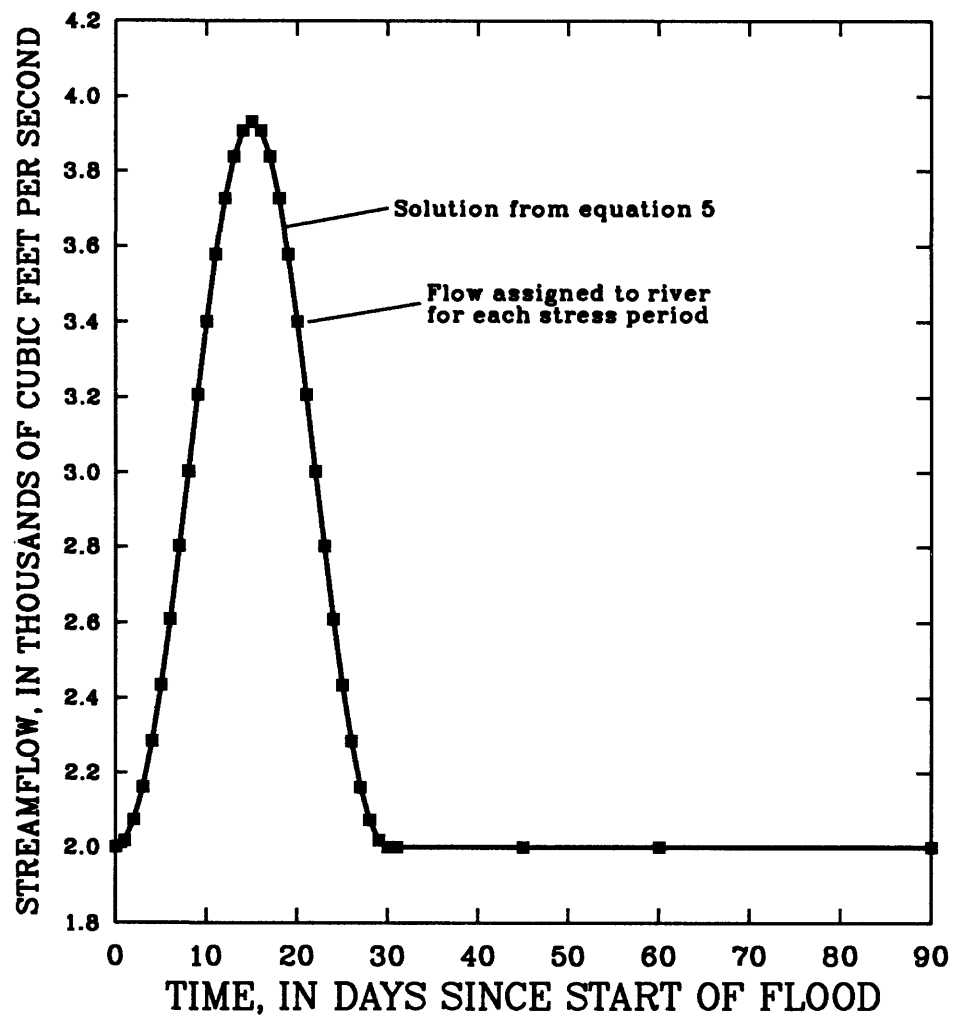
Figure 7.--Distribution of streamflow for a 30-day flood
event used for the simulation of test problem 2.

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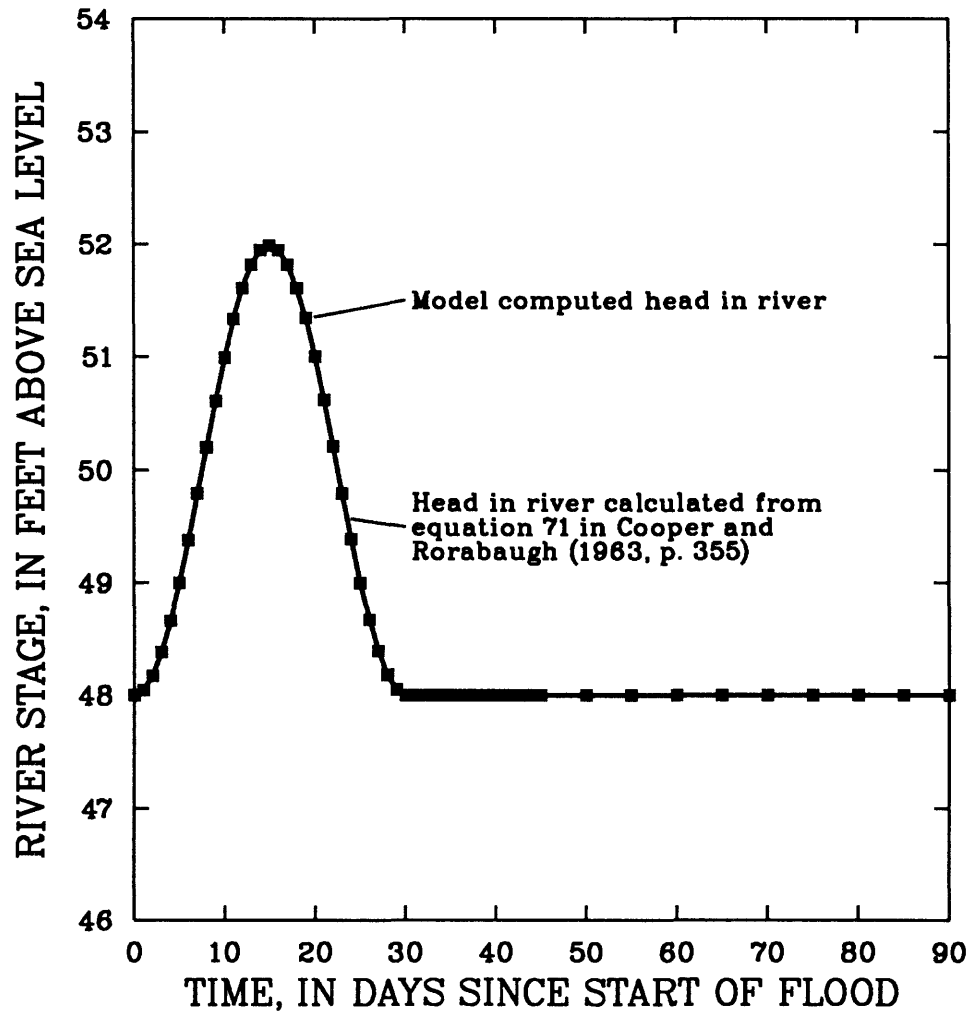
Figure 8.--Comparison of model computed river stage to
stage calculated from the Manning formula assuming
a rectangular stream channel (equation 5). Results
indicate that equation 5 has been correctly programmed
into the Streamflow-Routing Package.
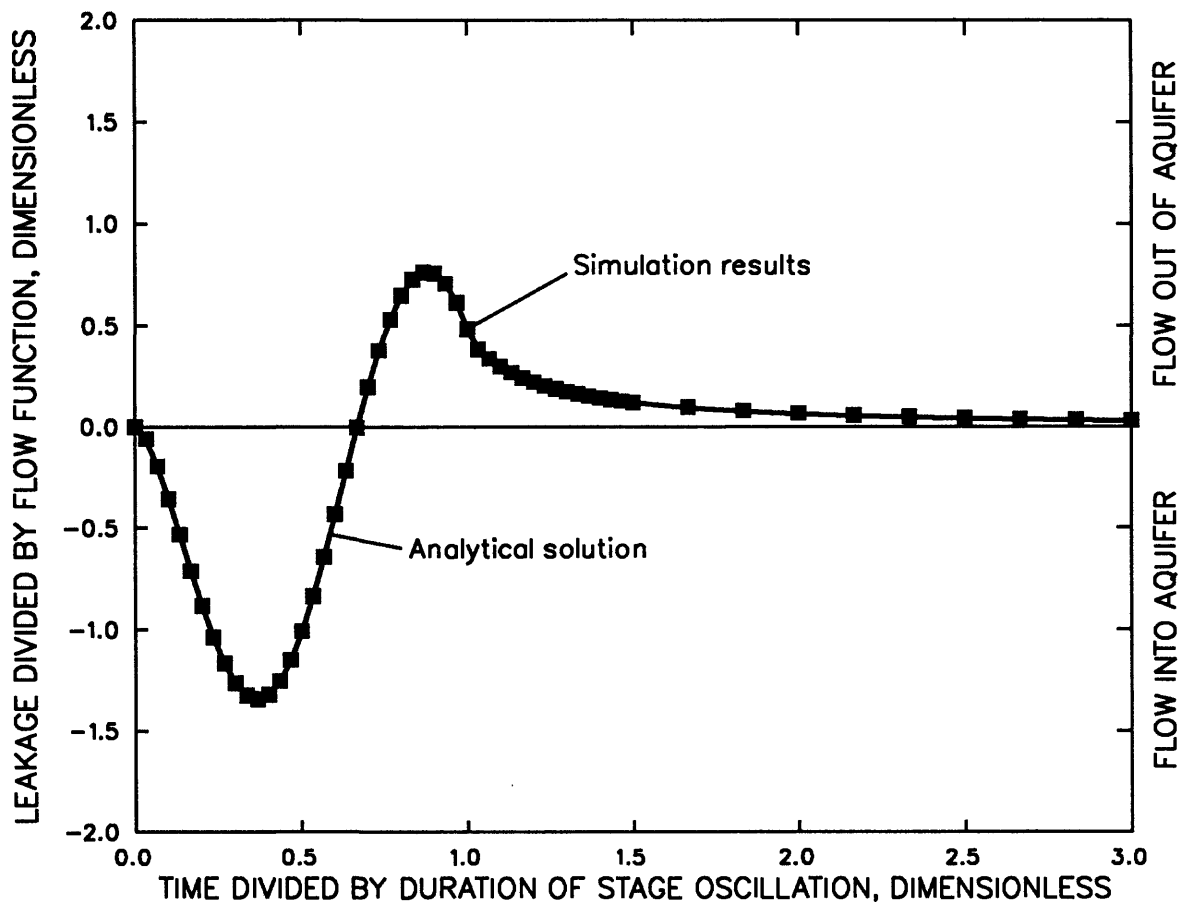
EXPLANATION OF LEAKAGE AND FLOW FUNCTION

Leakage = flow between river and aquifer per unit

river length, L^2 / T ,

Flow function = $(h_0 / 2) \sqrt{W\, T\, St}$, L^2 / T ,

where h_0 = maximum change in river stage, L ,

T = transmissivity, L^2 / T ,

St = storage coefficient, dimensionless, and

W = frequency of river stage change, which

equals two pi divided by duration of stage

oscillation, T^{-1} .

Figure 9.--Comparison of model computed flows into and out of aquifer
for test problem 2 to an analytical solution. The analytical solution
was developed by Cooper and Rorabaugh (1963) for a semi-infinite
aquifer (eqs. 81 and 82). Sign convention is opposite that used in
the finite-difference ground-water flow model but was used to be
consistent with Cooper and Rorabaugh.
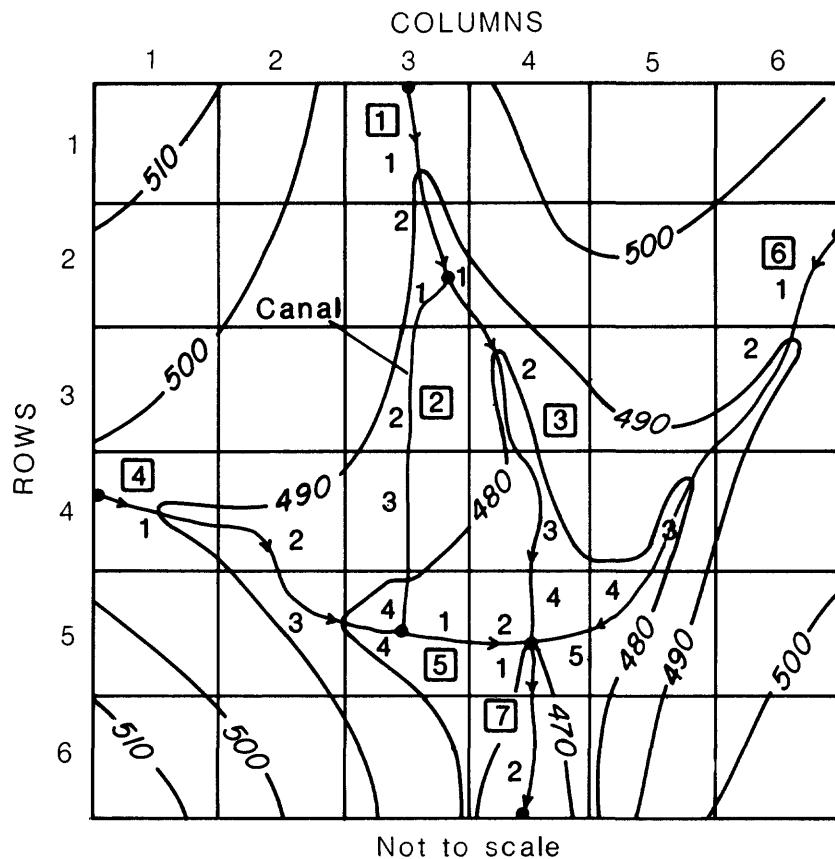
Figure 10.--Model grid, numbering system of streams and
diversions, and topographic contours for
example problem.

The example includes 7 stream segments with a total of 23 reaches. There is one diversion (segment 2) and two places where streams join (segments 2 and 4 join to make segment 5 and segments 3, 5, and 6 join to make segment 7). Stream stages are also computed for each reach and the necessary input is included in Appendix III and also table 2. The streams range in width from 5 to 10 ft. Streambed conductance values also vary depending on the length and width of each stream reach. The hydraulic conductivity of the streambed deposits is 4×10^{-4} ft/s. A steady state solution was simulated using average annual streamflows for each stream.

Water levels and streamflows and leakage between the stream reaches and aquifer are shown in figure 11. Total streamflow into the area was 6.5 ft^3/s with an equal amount of streamflow leaving the area. Leakage to the aquifer was 5.22 ft^3/s and leakage from the aquifer was 5.22 ft^3/s. The areas of leakage to the aquifer were generally the upstream areas while flow from the aquifer to the streams were generally in the downstream reaches. Several of the reaches went dry as leakage to the aquifer exceeded streamflows (shown in fig. 11) but downstream reaches began flowing when the head in the aquifer exceeded the top of the streambed. The data input and the simulation results are included in Appendix III.

The example illustrates that the Streamflow-Routing Package can simulate complex systems. It can also be used to simulate a variety of systems where aquifer properties change in space and where the amount and distribution of recharge and discharge can change in space and time.

IMPLEMENTATION OF STREAMFLOW-ROUTING PACKAGE IN THE GROUND-WATER FLOW MODEL

The Streamflow-Routing Package (STR1) is designed for incorporation into the ground-water flow model by McDonald and Harbaugh (1988). The package consists of four FORTRAN subroutines, referred to as modules, that carry out the following procedures: allocate memory, read and prepare data, formulate the finite-difference equations, and compute mass-balance components and print results. The modules are respectively named STR1AL, STR1RP, STR1FM, and STR1BD. The first three characters of the names identify the modules as being part of the Streamflow-Routing Package; the next character identifies the version number of the package; the last two characters identify the procedure performed in the module. The procedures used by the Streamflow-Routing Package are consistent with procedures used by existing packages in the ground-water flow model (fig. 12).

The MAIN program of the ground-water flow model must be modified to call the four modules of the Streamflow-Routing Package. The procedures on the left side of figure 12 are listed in the order each are carried out in the MAIN program of the model. Call statements to the modules of the Streamflow-Routing Package must be placed in sections of the MAIN program in which the particular procedure is being carried out for other packages. For example, the STR1AL module must be called within the section of the MAIN program in which other allocate modules (BAS1AL, RIV1AL, etc.) are called. In all sections of the MAIN program, the call to the Basic (BAS1) Package module (subroutine) must come before any other module call statements. Actually, the modules of the Streamflow-Routing Package could be used to replace the River Package in the model. The FORTRAN call statements to be added to the MAIN program are as follows:

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COLUMNS

1　2　3　4　5　6

ROWS

1

4.5

+0.93　490

2

490　1.2
+1.0

+0.84
1.5
-0.10　-1.0
1.2　485

3

+0.22
-0.66
480
+0.19

4

0.8
+0.45　+0.34　+0.36
-0.61
475
-0.06

5

+0.01
+0.22　0.8
+0.13
+0.46
+0.06
0.0　-0.18　3.9　0.0
-1.30

6

470
+1.25
6.5

Not to scale
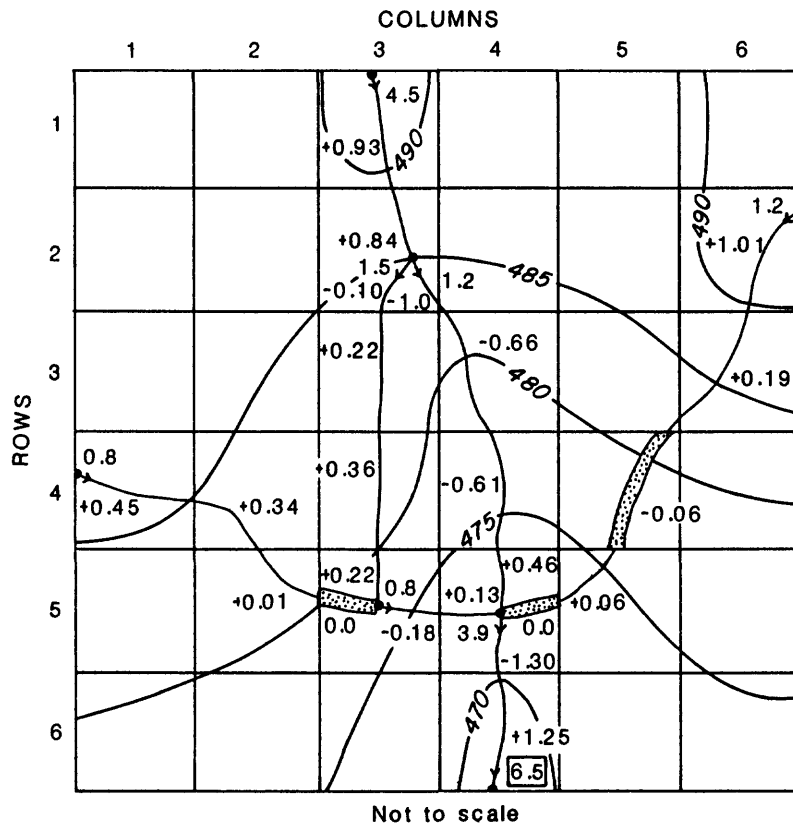
EXPLANATION

—480— GROUND-WATER LEVEL CONTOUR--
Shows elevation of ground-water level.
Contour interval 5 feet. Datum is
sea level.

4.5
STREAMFLOW INTO FIRST REACH OF
A SEGMENT--In cubic feet per second.
Arrow indicates direction of flow. Dots
identify individual segments.

6.5
STREAMFLOW OUT OF LAST REACH
OF LAST SEGMENT--In cubic feet per
second. Arrow indicates direction of flow.

+0.36
LEAKAGE BETWEEN STREAM AND AQUIFER
FOR EACH REACH--In cubic feet per
second. Positive value indicates flow from
stream to aquifer. Negative value indicates
flow from aquifer into stream.

DRY STREAM--Streamflow into reach is zero.
In these reaches, leakage from stream to
aquifer is zero but leakage from aquifer to
stream is still allowed.

Figure 11.--Simulation results for example problem.

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```
       IF (IUNIT(??).GT.0) CALL STR1AL(ISUM,LENX,LCSTRM,ICSTRM,MXSTRM,
      1                NSTREM,IUNIT(??),IOUT,ISTCB1,ISTCB2,NSS,NTRIB,
      2                NDIV,ICALC,CONST,LCTBAR,LCTRIB,LCIVAR)


       IF (IUNIT(??).GT.0) CALL STR1RP(X(LCSTRM),X(ICSTRM),NSTREM,
      1                MXSTRM,IUNIT(??),IOUT,X(LCTBAR),NDIV,NSS,
      2                NTRIB,X(LCIVAR),ICALC,IPTFLG)


       IF (IUNIT(??).GT.0) CALL STR1FM(NSTREM,X(LCSTRM),X(ICSTRM),
      1              X(LCHNEW),X(LCHCOF),X(LCRHS),X(LCIBOU),MXSTRM,
      2              NCOL,NROW,NLAY,IOUT,NSS,X(LCTBAR),NTRIB,
      3              X(LCTRIB),X(LCIVAR),ICALC,CONST)


       IF (IUNIT(??).GT.0) CALL STR1BD(NSTREM,X(LCSTRM),X(ICSTRM),
      1        X(LCIBOU),MXSTRM,X(LCHNEW),NCOL,NROW,NLAY,DELT,VBVL,
      2        VBNM,MSUM,KKSTP,KKPER,ISTCB1,ISTCB2,ICBCFL,X(LCBUFF),IOUT,
      3        NTRIB,NSS,X(LCTRIB),X(LCTBAR),X(LCIVAR),ICALC,CONST,IPTFLG)
```

    The user must specify a number between 13 and 24 for IUNIT(??), which is defined in the Basic Package (McDonald and Harbaugh, 1988, p. 4-9 through 4-12). Then whenever the Streamflow-Routing Package is to be used, a positive number is specified in the proper location in the Basic Package. This number corresponds to the FORTRAN unit number assigned to the Streamflow-Routing Package data set.

    The first call statement is added where space is allocated to the "X" array (between comments C4 and C5 in the MAIN program). The second statement is added where information for a package is read and prepared for each stress period (between comments C7B and C7C in the MAIN program). The third statement is added where the finite-difference equations are formulated for each time step (between comments C7C2A and C7C2B in the MAIN program). The last statement is added where budget terms are calculated for each time step (between comment C7C4 and C7C5 in the MAIN program).

    The four call statements are included in an example MAIN program at the end of section on module documentation. In the example, the IUNIT number is specified as 13. Thus, to activate the Streamflow-Routing Package for a simulation using the example MAIN program, a positive number must be specified to IUNIT 13 in the Basic (BAS1) Package. The number is the FORTRAN unit number assigned to the data input for the Streamflow-Routing Package.

    Information needed to simulate the effects of rivers, streams, canals and ditches on aquifer systems with the Streamflow-Routing Package is in a format similar to that of the River Package described in McDonald and Harbaugh (1988, p. 6-1 through 6-36). The instructions on the ordering of the data input is explained in the following section. A sample input data set is shown in table 2, which corresponds to the example in figures 1a and 10.

PACKAGES

PROCEDURES	BAS	BCF	WEL	RCH	RIV	DRN	EVT	GHB	SIP	SOR	STR
Define (DF)	BAS1DF										
Allocate (AL)	BAS1AL	BCF1AL	WEL1AL	RCH1AL	RIV1AL	DRN1AL	EVT1AL	GHB1AL	SIP1AL	SOR1AL	STR1AL
Read and Prepare (RP)	BAS1RP$_U$	BCF1RP$_{US}$							SIP1RP	SOR1RP	
Stress (ST)	BAS1ST										
Read and Prepare (RP)			WEL1RP	RCH1RP$_U$	RIV1RP	DRN1RP	EVT1RP$_U$	GHB1RP			STR1RP
Advance (AD)	BAS1AD										
Formulate (FM)	BAS1FM	BCF1FM$_S$	WEL1FM	RCH1FM	RIV1FM	DRN1FM	EVT1FM	GHB1FM			STR1FM
Approximate (AP)									SIP1AP$_S$	SOR1AP$_S$	
Output Control (OC)	BAS1OC										
Budget (BD)		BCF1BD$_{US}$	WEL1BD$_U$	RCH1BD$_U$	RIV1BD$_U$	DRN1BD$_U$	EVT1BD$_U$	GHB1BD$_U$			STR1BD$_U$
Output (OT)	BAS1OT$_U$										

Modified from McDonald and Harbaugh (1988, figure 15)

EXPLANATION

BCF1BD$_{US}$ NAME OF MODULE — Subscript, U, indicates that utility modules are utilized. Subscript, S, indicates that submodules are utilized.

Figure 12.--Primary modules of finite-difference ground-water flow model organized by procedure and package.

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TABLE 2.--Sample data set for Streamflow-Routing Package

[From example problem; see figures 1a and 10. For description of variables in the explanation, see the following section]

Data item	Explanation	Input records (values by Column Number fields 1–8)
1	MXSTRM,NSS,NTRIB,NDIV,ICALC,CONST, ISTCB1,ISTCB2	23 7 3 1 1 1.486 -1 0
2	ITMP,IRDFLG,IPTFLG--FIRST STRESS PERIOD	23 0 0

Data item 3 — LAY,ROW,COL,SEG,REACH,FLOW,STAGE,COND,SBOT,STOP (ONE RECORD FOR EACH REACH):

LAY	ROW	COL	SEG	REACH	FLOW	STAGE	COND	SBOT	STOP
1	3	1	1	1	4.5	495.0	1.20	490.0	492.0
1	3	2	1	2		490.0	0.60	485.0	487.0
1	3	2	2	1	1.5	487.0	0.20	483.0	485.0
1	3	3	2	2		486.0	0.40	482.0	484.0
1	3	3	2	3		480.0	0.20	476.0	478.0
1	4	4	2	4		486.0	0.40	481.0	483.0
1	4	3	3	1	-1.0	482.0	1.20	477.0	479.0
1	4	4	3	2		478.0	1.20	473.0	475.0
1	4	4	3	3		475.0	0.60	470.0	472.0
1	5	4	4	1	0.8	492.0	0.40	489.0	490.0
1	4	1	4	2		488.0	0.32	485.0	486.0
1	5	2	4	3		483.0	0.32	480.0	481.0
1	5	3	4	4		480.0	0.20	477.0	478.0
1	5	4	4	5		478.0	0.20	475.0	476.0
1	5	1	5	1	-1.0	474.0	0.80	471.0	472.0
1	5	2	5	2		495.0	0.80	491.0	493.0
1	2	1	6	1	1.2	490.0	0.80	486.0	488.0
1	4	3	6	2		480.0	0.60	476.0	478.0
1	5	4	6	3		477.0	0.20	473.0	475.0
1	5	5	6	4		474.0	0.60	470.0	472.0
1	5	1	7	1	-1.0	472.0	1.20	467.0	469.0
1	6	2	7	2		469.0		464.0	466.0

Data item 4 — WIDTH,SLOPE,ROUGH (ONE RECORD FOR EACH REACH):

WIDTH	SLOPE	ROUGH
10.	0.007	0.030
10.	0.007	0.030
5.	0.002	0.022
5.	0.002	0.022
5.	0.004	0.022
10.	0.005	0.030
10.	0.005	0.030
10.	0.005	0.030

TABLE 2.--Sample data set for Streamflow-Routing Package--Continued

Input records

Column Numbers

```
                1         2         3         4         5         6         7         8
       12345678901234567890123456789012345678901234567890123456789012345678901234567890
```

Data item | Explanation

4 WIDTH,SLOPE,ROUGH--CONTINUED _____

```
       5.   0.004  0.022
       5.   0.004  0.022
       5.   0.004  0.022
       5.   0.005  0.022
       5.   0.005  0.022
       5.   0.008  0.022
       5.   0.007  0.022
       5.   0.004  0.022
      10.   0.003  0.030
      10.   0.004  0.030
```

ONE RECORD FOR EACH REACH

5 ITRIB(1),ITRIB(2),.... ITRIB(NTRIB) _____

```
    0 0   0
    0 0   0
    1 0   0
    0 0   0
    2 4   0
    0 5   0
    3 5   6
```

ONE RECORD FOR EACH SEGMENT

6 IUPSEG _____

```
    0
    1
    0
    0
    0
    0
```

ONE RECORD FOR EACH SEGMENT

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Input Instructions

FOR EACH SIMULATION:

STR1AL

1. Data: MXSTRM NSS NTRIB NDIV ICALC CONST ISTCB1 ISTCB2
   Format: I10   I10   I10   I10   I10   F10.0   I10   I10

FOR EACH STRESS PERIOD:

STR1RP

2. Data: ITMP   IRDFLG   IPTFLG
   Format: I10   I10   I10

3. Data: Layer Row Col Seg Reach Flow Stage Cond Sbot Stop
   Format: I5   I5   I5   I5   I5   F15.0 F10.0 F10.0 F10.0 F10.0
   (Item 3 normally consists of one record for each reach.
   Records are read in sequential order from upstream to
   downstream, first by segments, and then by reaches. The
   downstream ordering and reading of segments and reaches are
   important as the order determines the connection of inflows
   and outflows. If ITMP is negative or zero, items 3-6 are not
   read.)

If stream stages for each reach are to be calculated (ICALC>0), then
the following data set is read in sequential order of segment and reach.

4. Data: Width   Slope   Rough
   Format: F10.0   F10.0   F10.0

If the maximum number of tributaries (NTRIB) that can join a segment is
greater than zero, then the following data set is read. One record for each
segment is read in sequential order. A record is necessary even for
segments that do not have tributaries. In this case a blank record or a
record with all zeros is read.

5. Data: Itrib(1)   Itrib(2)   ...   Itrib(NTRIB)
   Format: I5   I5   ...   I5

If diversions are specified (NDIV>0), then the following data set is
read. One record is read for each segment in sequential order. For
segments that are not diversions, zeros or blanks are specified for each
input item.

6. Data: Iupseg
   Format: I10

Explanation of Fields Used in Input Instructions

MXSTRM   --is the maximum number of stream reaches that can be active during the simulation.

NSS   --is the maximum number of segments that can be used during the simulation.

NTRIB   --is the maximum number of tributary segments that can join during a simulation. Ten is the maximum number allowed as currently specified in the program.

NDIV   --is a flag, which when positive, specifies that diversions from segments are to be simulated.

ICALC   --is a flag, which when positive, specifies that stream stages in reaches are to be calculated.

CONST   --is a constant value used in calculating stream stage in reaches. It is specified whenever ICALC is greater than zero. This constant is 1.486 for flow units of cubic feet per second and 1.0 for units of cubic meters per second. The constant must be multiplied by 86,400 when using time units of days in the simulation. (For an explanation of time units, see McDonald and Harbaugh, 1988, p. 4-10.)

ISTCB1   --is a flag and a unit number.

   If ISTCB1>0, it is the unit number to which leakage between each stream reach and the corresponding model cell will be saved on disk whenever the variable ICBCFL is specified. (See McDonald and Harbaugh, 1988, p. 4-15, for details about the Output Control Package used to specify ICBCFL.)

   If ISTCB1=0, leakage between each reach and corresponding model cell will not be printed nor filed on disk.

   If ISTCB1<0, streamflows into and out of each reach and leakage between each reach and corresponding model cell will be printed whenever the variable ICBCFL is specified.

ISTCB2   --is a flag and unit number for an option of storing streamflow out of each reach instead of having the results printed.

   If ISTCB2>0, it is the unit number where streamflow out of each reach will be saved on disk whenever the variable ICBCFL is specified.

   If ISTCB2$\leq$0, streamflows out of each reach will not be saved on disk.

ITMP   --is a flag and a counter.

        If ITMP<0, stream data from the last stress period will be reused.

        If ITMP≥0, ITMP will be the number of reaches active during the current stress period.

IRDFLG   --is a flag, which when positive, suppresses printing of the input data set specified for a stress period. The input data set is printed for a stress period if the value is zero or blank.

IPTFLG   --is a flag, which when positive, suppresses printing of results for a stress period. The results are printed for a stress period if the value is zero or blank and whenever the variable ICBCFL is specified.

Layer   --is the layer number of the cell containing the stream reach.

Row   --is the row number of the cell containing the stream reach.

Col   --is the column number of the cell containing the stream reach.

Seg   --is a number assigned to a group of reaches. Segments must be numbered in downstream order and are read into the program in sequential order.

Reach   --is a sequential number in a segment that begins with one for the farthest upstream reach and continues in downstream order to the last reach in the segment. Reaches must be read in sequentially as the order reaches are read into the program determines the order of connection of inflows and outflows.

Flow   --is the streamflow, in length cubed per time, entering a segment. This value is specified only for the first reach in each segment. The value is either a zero or a blank when the reach number (Reach) is not 1. When inflow into a segment is the sum of outflow from a specified number of tributary segments, the segment inflow values are specified as a -1. (Note: if the specified inflow to a diversion is greater than the flow in the reach from which flow is to be diverted, then no flow is diverted from the stream.)

Stage   --is the stream stage, in units of length.

Cond   --is the streambed hydraulic conductance, in units of length squared per time.

Sbot   --is the elevation of the bottom of the streambed, in units of length.

Stop   --is the elevation of the top of the streambed, in units of length.

Width   --is the width of the stream channel, in units of length. It is used only when stream stage in each reach is calculated.

Slope   --is the slope of the stream channel in each reach, in units of
         length per length. It is used only when stream stage in each reach
         is calculated.

Rough   --is Manning's roughness coefficient for each stream reach. It is
         used only when stream stage in each reach is calculated.

Itrib(1)--for a segment that has tributary segments, Itrib(1) is the number
         of the first tributary segment. For a segment with no
         tributaries, Itrib(1) must be specified as zero.

Itrib(2)--for a segment that has tributary segments, Itrib(2) is the number
         of the second tributary segment. For a segment with no or only
         one tributary segment, Itrib(2) must be specified as zero.

Iupseg   --for a diversion segment, Iupseg is the number of the upstream
         segment from which water is diverted. For a segment that is not a
         diversion, Iupseg must be specified as zero.

MODULE DOCUMENTATION FOR THE STREAMFLOW-ROUTING PACKAGE

The Streamflow-Routing Package (STR1) consists of four modules
(subroutines), all of which are called by the MAIN program. The modules
are:

    STR1AL   Allocates space for arrays used in the package.

    STR1RP   Reads all data needed by package and initializes reach
                 inflow, outflow, and leakage arrays.

    STR1FM   Calculates leakage to and from stream reaches and adds
                 appropriate terms to finite-difference equations used to
                 calculate heads in aquifer and simulate ground-water flow.

    STR1BD   Calculates rates and accumulated volumes of stream leakage
                 into and out of aquifer. Results are either saved on files
                 or printed.

Module STR1AL

Module STR1AL allocates space for two lists (STRM and ISTRM) which will
contain an entry for each stream reach. Each entry in the ISTRM list
includes the location of the cell containing a reach, segment number and the
reach number. Each entry in the STRM list includes the streamflow into the
segment (unless outflow from tributary streams are to be added then a -1 is

entered), stream stage, conductance of the streambed, and the elevation of the bottom and the top of the streambed. If the stream stage in the reaches are to be calculated, the list also includes the width of the stream channel, the slope of the channel, and Manning's roughness coefficient. In addition, the module allocates space for three other lists (ITRBAR, ARTRIB, and IDIVAR), which will contain an entry for each segment. The ITRBAR list includes an entry for each tributary segment. The ARTRIB list is where outflow from each segment is saved and the IDIVAR list includes an entry for each segment that specifies (if any) the upstream segment number from which water is diverted.

Narrative of Module STR1AL

Module STR1AL allocates space in the X array of the modular model (McDonald and Harbaugh, 1988) so the lists needed for stream reaches and segments can be stored in the computer. A generalized flow chart of the module is shown in figure 13. A description of the steps shown in the flow chart follows:

1. Print a message identifying the package and initialize NSTREM (number of stream reaches).

2. Read and print MXSTRM (the maximum number of stream reaches), NSS (number of segments), NTRIB (maximum number of tributary segments that can join to form another segment), NDIV (flag that allows diversions from streams), ICALC (flag that specifies that stream stage for each reach will be calculated), CONST (a constant used in calculating stream stage), ISTCB1 (the unit number for saving on disk the leakage between each reach and the corresponding model cell or a flag indicating whether the flows for each reach and the leakage between the stream reach and corresponding model cell should be printed), and ISTCB2 (the unit number for saving on disk streamflow out of each reach).

3. Set LCSTRM, which is referenced to the first element in the stream list (STRM), equal to ISUM, which is currently referenced to the first unallocated element in the X array.

4. Calculate the amount of space needed for the stream list [11 values for each reach--(1) segment inflow, (2) stream stage, (3) streambed conductance, (4) streambed bottom and (5) top elevations, (6) stream width, (7) channel slope, (8) Manning's roughness coefficient, (9) streamflow out of each reach, (10) streamflow into each reach, (11) leakage through the streambed in each reach] and add it to ISUM.

5. Set ICSTRM equal to ISUM and calculate the amount of space needed for the ISTRM list (five values are needed for each reach--row, column, layer, segment number, and reach number). Add the space to ISUM.

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6. Set LCTBAR equal to ISUM and calculate the amount of space needed for the ITRBAR list (NTRIB values are needed for each segment). Add the space to ISUM.

7. Set LCTRIB equal to ISUM and calculate the amount of space needed for the ARTRIB list (one value is needed for each segment). This list stores the calculated streamflows out of each segment. Add the space to ISUM.

8. Set LCIVAR equal to ISUM and calculate the amount of space needed for the IDIVAR list (one value is needed for each segment and is the number of the segment that water is to be diverted). Add the space to ISUM.

9. Print the number of elements in the X array used by the Streamflow-Routing Package.

10. RETURN to MAIN program.

Figure 13.--Generalized flow chart of module STR1AL. Variable names are defined in section 'List of variables for module STR1AL.'

```
      SUBROUTINE STR1AL(ISUM,LENX,LCSTRM,ICSTRM,MXSTRM,NSTREM,IN,
     1                  IOUT,ISTCB1,ISTCB2,NSS,NTRIB,NDIV,ICALC,CONST,
     2                  LCTBAR,LCTRIB,LCIVAR)
C                                                                      C
C-----VERSION    1 23OCT1987 STR1AL                                    C
C     ****************************************************************C
C     ALLOCATE ARRAY STORAGE FOR STREAMS                              C
C     ****************************************************************C
C                                                                      C
C     SPECIFICATIONS:                                                 C
C     -----------------------------------------------------------------C
C     -----------------------------------------------------------------C
C                                                                      C
C1------IDENTIFY PACKAGE AND INITIALIZE NSTREM.                        C
      WRITE(IOUT,1) IN
    1 FORMAT(1H0,'STRM -- STREAM PACKAGE, VERSION 1, 10/23/87',
     1'INPUT READ FROM UNIT ',I3)
      NSTREM=0
C                                                                      C
C2------ READ MXSTRM, NSS, NTRIB, ISTCB1, AND ISTCB2.                  C
  100 READ(IN,3)MXSTRM,NSS,NTRIB,NDIV,ICALC,CONST,ISTCB1,ISTCB2
    3 FORMAT(5I10,F10.0,2I10)
      IF(MXSTRM.LT.0)MXSTRM=0
      IF(NSS.LT.0)NSS=0
      WRITE(IOUT,4)MXSTRM,NSS,NTRIB
    4 FORMAT(1H ,'MAXIMUM OF',I5,' STREAM NODES'//1X,'NUMBER OF STREAM S
     1EGMENTS IS ',I5//1X,'NUMBER OF STREAM TRIBUTARIES IS ',I5//)
      IF(NDIV.GT.0) WRITE(IOUT,5)
    5 FORMAT(1H ,'DIVERSIONS FROM STREAMS HAVE BEEN SPECIFIED')
      IF(ICALC.GT.0) WRITE(IOUT,6) CONST
    6 FORMAT(1H ,'HEADS IN STREAMS WILL BE CALCULATED USING A CONSTANT
     1OF ',F10.4)
      IF(ISTCB1.GT.0) WRITE(IOUT,7) ISTCB1,ISTCB2
    7 FORMAT(1X,'CELL BUDGETS WILL BE SAVED ON UNITS',I3,'AND',I3)
C                                                                      C
C3------SET LCSTRM EQUAL TO ADDRESS OF FIRST UNUSED SPACE IN X.        C
  200 LCSTRM=ISUM
C                                                                      C
C4------CALCULATE AMOUNT OF SPACE NEEDED FOR STRM LIST.                C
      ISPA=11*MXSTRM
      ISUM=ISUM+ISPA
C                                                                      C
C5------CALCULATE AMOUNT OF SPACE NEEDED FOR ISTRM LIST.               C
      ICSTRM=ISUM
      ISPB=5*MXSTRM
      ISUM=ISUM+ISPB
C                                                                      C
C6------CALCULATE AMOUNT OF SPACE NEEEDED FOR ITRBAR LIST.             C
      LCTBAR=ISUM
      ISPC=NSS*NTRIB
```

```
      ISUM=ISUM+ISPC
C                                                                        C
C7------CALCULATE AMOUNT OF SPACE NEEDED FOR ARTRIB LIST.                C
      LCTRIB=ISUM
      ISPD=NSS
      ISUM=ISUM+ISPD
C                                                                        C
C8------CALCULATE AMOUNT OF SPACE NEEDED FOR IDIVAR LIST.                C
      LCIVAR=ISUM
      ISPE=NSS
      ISUM=ISUM+ISPE
      ISP=ISPA+ISPB+ISPC+ISPD+ISPE
C                                                                        C
C9------PRINT AMOUNT OF SPACE USED BY STREAM PACKAGE.                    C
      WRITE (IOUT,8)ISP
    8 FORMAT(1X,I8,' ELEMENTS IN X ARRAY ARE USED FOR STREAMS')
      ISUM1=ISUM-1
      WRITE(IOUT,9)ISUM1,LENX
    9 FORMAT(1X,I8,' ELEMENTS OF X ARRAY USED OUT OF',I7)
      IF(ISUM1.GT.LENX) WRITE(IOUT,10)
   10 FORMAT(1X,'    ***X ARRAY MUST BE DIMENSIONED LARGER***')
C                                                                        C
C10-----RETURN.                                                          C
      RETURN
      END
```

List of Variables for Module STR1AL

Variable	Range	Definition
CONST	Package	A constant used in calculating stream stage in reaches. Specified only when ICALC is greater than zero. A value of 1.486 is used for units of cubic feet per second and a value of 1.0 is used for units of cubic meters per second. The value must be multiplied by 86,400 when days are used as the time unit.
ICALC	Package	Flag. >0, stream stage in reaches will be calculated. ≤0, stream stage in reaches will not be calculated.
ICSTRM	Package	Location in X array of first element in ISTRM list.
IN	Package	Primary unit number from which input for this package will be read.
IOUT	Global	Primary unit number for all printed output.
ISTCB1	Package	Flag and unit number. >0, unit number to which leakage between each reach and corresponding model cell is saved on disk whenever the variable ICBCFL is specified in the Output Control Package (McDonald and Harbaugh, 1988, p. 4-15). =0, leakage will not be printed nor recorded. <0, leakage between each reach and corresponding model cell and reach inflow and outflow are printed whenever the variables ICBCFL and IPTFLG are specified.
ISTCB2	Package	Flag and unit number. >0, unit number to which streamflow out of each stream reach will be saved on disk whenever the variable ICBCFL is specified. ≤0, streamflow out of each reach will not be saved on disk.
ISPA	Module	Number of words in X array allocated to the STRM list by this module.

ISPB	Module	Number of words in X array allocated to the ISTRM list by this module.
ISPC	Module	Number of words in X array allocated to the ITRBAR list by this module.
ISPD	Module	Number of words in X array allocated to the ARTRIB list by this module.
ISPE	Module	Number of words in X array allocated to the IDIVAR list by this module.
ISP	Module	Total number of words in X array allocated by this module.
ISUM	Global	Index number of lowest element in X array which has not yet been allocated.
ISUM1	Module	ISUM minus one.
LCIVAR	Package	Location in X array of first element in the IDIVAR list.
LCSTRM	Package	Location in X array of first element in the STRM list.
LCTBAR	Package	Location in X array of first element in the ITRBAR list.
LCTRIB	Package	Location in X array of first element in the ARTRIB list.
LENX	Global	Length of the X array in words. This should always be equal to the dimension of the X specified in the MAIN program.
MXSTRM	Package	Maximum number of stream reaches active during the simulation.
NDIV	Package	Flag. >0, diversions from segments will be specified. ≤0, no diversions from segments will be specified.
NSS	Package	Maximum number of stream segments.
NSTREM	Package	Number of stream reaches active during current stress period.
NTRIB	Package	Maximum number of tributary segments that join one downstream segment.

Module STR1RP

Module STR1RP reads for each model cell containing a stream reach, the location of the cell, the segment and reach numbers, streamflow into the segment, stream stage, conductance of the streambed, and elevation of the bottom and top of the streambed. If the stream stage in each reach is to be calculated, then the module also reads for each reach, the width of the stream channel, the slope of the channel, and Manning's roughness coefficient. If outflow from two or more tributary stream segments is to be added as inflow to a downstream segment, then the module reads for each segment, the segments that are tributary to it. If diversions are to be subtracted from segments, then the module reads for each segment the upstream segment from which water is diverted.

Narrative for Module STR1RP

The module STR1RP reads and records data needed for each of the lists used by the Streamflow-Routing Package. A generalized flow chart of the module is shown in figure 14. A description of the steps shown in the flow chart follows:

1. Read ITMP, IRDFLG, IPTFLG. If ITMP is greater than or equal to zero, it is the number of stream reaches active during the current stress period, or when less than zero, it indicates that the stream data used in the last stress period will be used in the current stress period. If IRDFLG and IPTFLG are positive, then the input data set and the results will not be printed for the stress period.

2. Test ITMP. If ITMP is negative, print message that indicates data from the last stress period will be used and then return to MAIN program. If ITMP is greater than or equal to zero, set the number of active stream reaches (NSTREM) in the current stress period equal to ITMP.

3. Compare the number of stream reaches (NSTREM) in the current stress period to the number specified as the maximum for the simulation (MXSTRM). If NSTREM is greater than MXSTRM then STOP. If NSTREM is less than or equal to MXSTRM then print the number of stream reaches (NSTREM) used in the current stress period.

4. Check the number of stream reaches. If NSTREM is zero for the current stress period then return to MAIN program.

5. Read and print (print if IRDFLG is zero) for each stream reach: the layer, row, column, segment number, reach number, stream segment inflow, stream head, streambed conductance, and the elevation of the bottom and top of the streambed.

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6. Check if ICALC is greater than zero. If ICALC is greater than zero, read and print (print if IRDFLG is zero) the channel width, channel slope, and Manning's roughness coefficient for each reach stream. If ICALC is less than or equal to zero, no data is read.

7. Initialize the ITRBAR list to zero.

8. Initialize the IDIVAR list to zero.

9. Read and print (print if IRDFLG is zero) for each segment the tributary segments. One record of NTRIB values is read for each segment even though some segments have no tributaries. The maximum number of tributary segments is 10. The number is currently set in the program but could be changed if needed (Format statements 11 and 12).

10. Check if NDIV is greater than zero. If NDIV is greater than zero, read and print (print if IRDFLG is zero) for each segment the segments in which water is diverted. A zero value is assigned to segments that do not divert water.

11. Initialize to zero for each reach, the reach inflow, outflow, and leakage to or from the aquifer system.
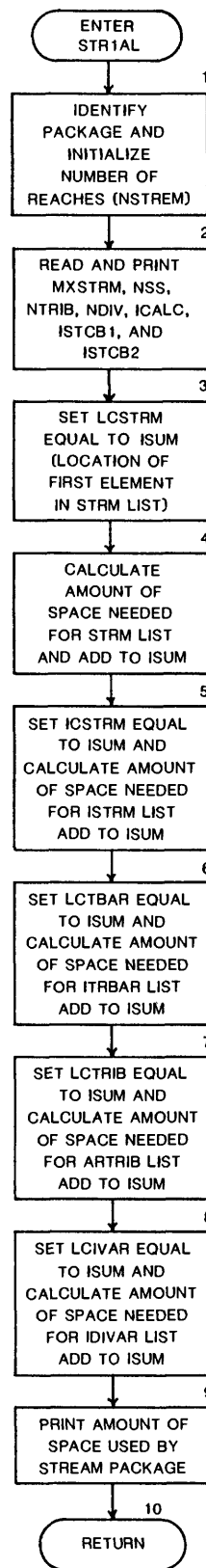
12. RETURN to MAIN program.
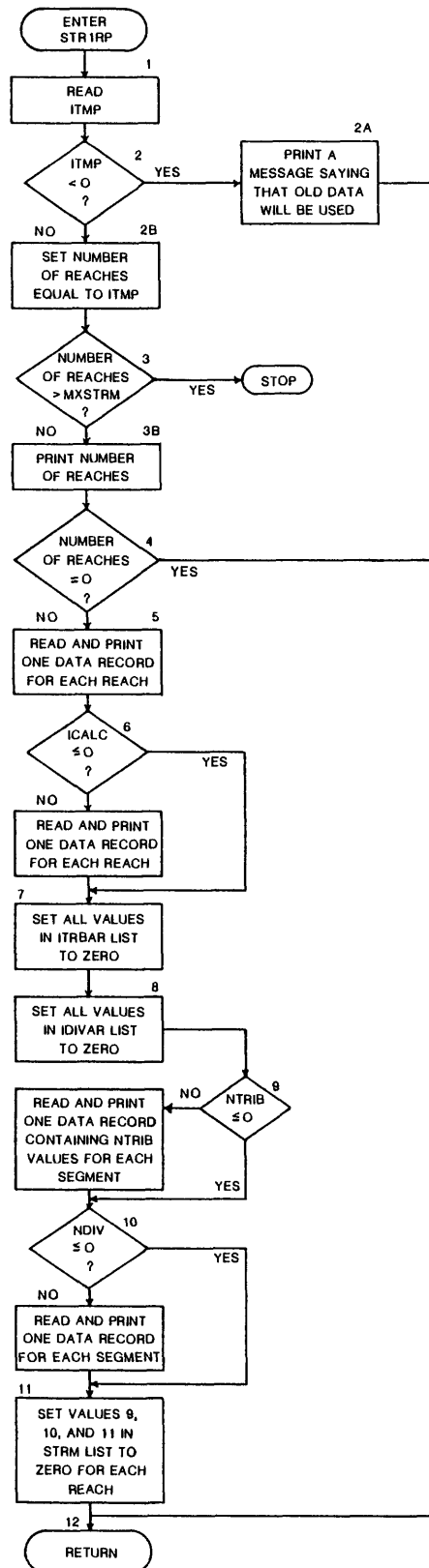
Figure 14.--Generalized flow chart of module STR1RP. Variable names are defined in section 'List of variables for module STR1RP.'

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```
      SUBROUTINE STR1RP(STRM,ISTRM,NSTREM,MXSTRM,IN,IOUT,ITRBAR,NDIV,
     1                  NSS,NTRIB,IDIVAR,ICALC,IPTFLG)
C                                                                       C
C                                                                       C
C-----VERSION   1 23OCT1987 STR1RP                                      C
C     ****************************************************************** C
C     READ STREAM DATA:  INCLUDES SEGMENT AND REACH NUMBERS, CELL       C
C         SEQUENCE OF SEGMENT AND REACH, FLOW INTO MODEL AT BOUNDARY,   C
C         STREAM STAGE, STREAMBED CONDUCTANCE, AND STREAMBED TOP AND    C
C         BOTTOM ELEVATIONS                                             C
C     ****************************************************************** C
C                                                                       C
C     SPECIFICATIONS:                                                   C
C     ----------------------------------------------------------------- C
      DIMENSION STRM(11,MXSTRM),ISTRM(5,MXSTRM),ITRBAR(NSS,NTRIB),
     1          IDIVAR(NSS)
C     ----------------------------------------------------------------- C
C                                                                       C
C1A-----IF MXSTREAM IS LESS THAN 1 THEN STREAM IS INACTIVE. RETURN.     C
      IF(MXSTRM.LT.1) RETURN
C                                                                       C
C1B-----READ ITMP(NUMBER OF STREAM REACHES OR FLAG TO REUSE DATA).      C
      READ(IN,1)ITMP,IRDFLG,IPTFLG
    1 FORMAT(3I10)
C                                                                       C
C2A-----IF ITMP <0 THEN REUSE DATA FROM LAST STRESS PERIOD.             C
      IF(ITMP.GE.0)GO TO 50
      WRITE(IOUT,2)
    2 FORMAT(1H0,'REUSING STREAM NODES FROM LAST STRESS PERIOD')
      RETURN
C                                                                       C
C2B-----IF ITMP=> ZERO THEN IT IS THE NUMBER OF STREAM REACHES.         C
   50 NSTREM=ITMP
C                                                                       C
C3A-----IF NSTREM>MXSTRM THEN STOP.                                     C
      IF(NSTREM.LE.MXSTRM)GO TO 100
      WRITE(IOUT,99)NSTREM,MXSTRM
   99 FORMAT(1H0,'NSTREM(',I4,') IS GREATER THAN MXSTRM(',I4,')')
      STOP
C                                                                       C
C3B-----PRINT NUMBER OF STREAM REACHES IN THIS STRESS PERIOD.           C
  100 IF(IRDFLG.EQ.0) WRITE(IOUT,3)NSTREM
    3 FORMAT(1H0,//1X,I5,' STREAM NODES')
C                                                                       C
C4------IF THERE ARE NO STREAM CELLS THEN RETURN.                       C
      IF(NSTREM.EQ.0) RETURN
C                                                                       C
C5------READ AND PRINT DATA FOR EACH STREAM REACH.                      C
      IF(IRDFLG.EQ.0) WRITE(IOUT,4)
    4 FORMAT(1H ,3X,'LAYER    ROW     COL    SEGMENT   REACH   STREAMFLOW
```

```
      1    STREAM     STREAMBED      STREAMBED BOT   STREAMBED TOP',/27X,
      2'NUMBER    NUMBER                      STAGE    CONDUCTANCE       ELEVAT
      3ION        ELEVATION',/3X,110('-'))
       DO 250 II=1,NSTREM
       READ(IN,5)K,I,J,ISTRM(4,II),ISTRM(5,II),STRM(1,II),STRM(2,II),
      1STRM(3,II),STRM(4,II),STRM(5,II)
     5 FORMAT(5I5,F15.0,4F10.0)
       IF(IRDFLG.EQ.0) WRITE(IOUT,6)K,I,J,ISTRM(4,II),ISTRM(5,II),
      1STRM(1,II),STRM(2,II),STRM(3,II),STRM(4,II),STRM(5,II)
     6 FORMAT(1X,3X,I4,2I7,2I9,7X,G11.4,G12.4,G11.4,4X,2G13.4)
       ISTRM(1,II)=K
       ISTRM(2,II)=I
       ISTRM(3,II)=J
   250 CONTINUE
C                                                                       C
C6----READ AND PRINT DATA IF STREAM STAGE  IS CALCULATED.               C
       IF(ICALC.LE.0) GO TO 300
       IF(IRDFLG.EQ.0) WRITE(IOUT,7)
     7 FORMAT(1H0,3X,'LAYER',3X,'ROW',4X,'COL  ',' SEGMENT',3X,
      1'REACH',8X,'STREAM',13X,'STREAM',10X,'ROUGH',/27X,'NUMBER',3X,
      2 'NUMBER',8X,'WIDTH',14X,'SLOPE',10X,'COEF.',/3X,110('-'))
       DO 280 II=1,NSTREM
       READ(IN,8) STRM(6,II),STRM(7,II),STRM(8,II)
     8 FORMAT(3F10.0)
       IF(IRDFLG.EQ.0) WRITE(IOUT,9)ISTRM(1,II),ISTRM(2,II),ISTRM(3,II),
      1ISTRM(4,II),ISTRM(5,II),STRM(6,II),STRM(7,II),STRM(8,II)
     9 FORMAT(4X,I4,2I7,2I9,7X,G12.4,4X,G13.4,4X,G12.4)
   280 CONTINUE
C                                                                       C
C7------INITIALIZE ALL TRIBUTARY SEGMENTS TO ZERO.                      C
   300 DO 320 IK=1,NSS
       DO 320 JK=1,NTRIB
       ITRBAR(IK,JK)=0
   320 CONTINUE
C                                                                       C
C8-----INITIALIZE DIVERSION SEGMENT ARRAY TO ZERO.                      C
       DO 325 IK=1,NSS
       IDIVAR(IK)=0
   325 CONTINUE
C                                                                       C
C9-----READ AND PRINT TRIBUTARY SEGMENTS.                               C
       IF(NTRIB.LE.0) GO TO 343
       IF(IRDFLG.EQ.0) WRITE(IOUT,10)NTRIB
    10 FORMAT(1H0,30X,'MAXIMUM NUMBER OF TRIBUTARY STREAMS IS ',I5,//1X,
      1 20X,'STREAM SEGMENT',15X,'TRIBUTARY STREAM SEGMENT NUMBERS')
       DO 340 IK=1,NSS
       READ(IN,11) (ITRBAR(IK,JK),JK=1,NTRIB)
    11 FORMAT(10I5)
       IF(IRDFLG.EQ.0) WRITE(IOUT,12)IK,(ITRBAR(IK,JK),JK=1,NTRIB)
    12 FORMAT(20X,I5,20X,10I5)
   340 CONTINUE
C                                                                       C
C10----READ AND PRINT DIVERSION SEGMENT NUMBERS.                        C
   343 IF(NDIV.LE.0) GO TO 350
```

```
      IF(IRDFLG.EQ.0) WRITE(IOUT,13)
   13 FORMAT(1H0,10X,'DIVERSION SEGMENT NUMBER',10X,
     1        'UPSTREAM SEGMENT NUMBER')
      DO 345 IK=1,NSS
      READ(IN,14) IDIVAR(IK)
   14 FORMAT(I10)
      IF(IRDFLG.EQ.0) WRITE(IOUT,15) IK,IDIVAR(IK)
   15 FORMAT(20X,I5,28X,I5)
  345 CONTINUE
C                                                                      C
C11----SET FLOW OUT OF REACH, FLOW INTO REACH, AND FLOW THROUGH        C
C       STREAM BED TO ZERO.                                            C
  350 DO 360 II =1,NSTREM
      STRM(9,II)=0.0
      STRM(10,II)=0.0
      STRM(11,II)=0.0
  360 CONTINUE
C                                                                      C
C12------RETURN.                                                       C
      RETURN
      END
```

List of Variables for Module STR1RP

<u>Variable</u>	<u>Range</u>	<u>Definition</u>
I	Module	Row number of model cell containing a stream reach.
ICALC	Package	Flag. >0, stream stage in reaches will be calculated. ≤0, stream stage in reaches will not be calculated.
IDIVAR	Package	DIMENSION (NSS), For each segment: upstream segment number from which water is to be diverted.
II	Module	Index for reach.
IK	Module	Index for segment.
IN	Package	Primary unit number from which input for this package will be read.
IOUT	Global	Primary unit number for all printed output.
IPTFLG	Package	Flag to specify printing of results for each stress period. Results may be printed at selected time steps within a stress period depending on the value specified for variable ICBCFL in the Output Control Package (McDonald and Harbaugh, 1988, p. 4-15). 0, results will be printed according to the value of ICBCFL. >0, results will not be printed even if ICBCFL is specified.
IRDFLG	Module	Flag to specify printing of input data set for each stress period. 0, input data will be printed. >0, input data will not be printed.
ISTRM	Package	DIMENSION (5,MXSTRM), For each reach: layer, row, column, segment number, and reach number.

ITMP	Package	Flag or number of reaches. ≥ 0, number of reaches active during current stress period. < 0, same reaches active last stress period will be active during the current stress period.
ITRBAR	Package	DIMENSION (NSS,NTRIB), For each segment: segment numbers of each tributary segment. A zero is assigned if no segments are tributary to a given segment.
J	Module	Column number of model cell containing a stream reach.
JK	Module	Index for tributary segments.
K	Module	Layer number of model cell containing a stream reach.
MXSTRM	Package	Maximum number of stream reaches active during the simulation.
NDIV	Package	Flag. > 0, diversions from segments will be specified. ≤ 0, no diversions from segments will be specified.
NSS	Package	Maximum number of stream segments.
NSTREM	Package	Number of stream reaches active during the current stress period.
NTRIB	Package	Maximum number of tributary segments that join one downstream segment.
STRM	Package	DIMENSION (11,MXSTRM), For each reach: (1) segment inflow, (2) stream stage, (3) streambed conductance, (4) streambed bottom and (5) top elevations, (6) stream width, (7) channel slope, (8) Manning's roughness coefficient, (9) streamflow out of each reach, (10) streamflow into each reach, and (11) leakage through the streambed in each reach.

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Module STR1FM

Module STR1FM calculates leakage from each stream reach to the corresponding model cell and subtracts the leakage from streamflow into each reach. The module then adds the appropriate terms to the finite-difference equation for each model cell that contains a stream reach. If streamflow in a reach is zero, then no terms are added to the finite-difference equation for the corresponding model cell.

Narrative for Module STR1FM

The module STR1FM routes flow in streams and adds terms representing stream leakage to the accumulators HCOF and RHS in equation 26 of McDonald and Harbaugh (1988, p. 2-26). A generalized flow chart of the module is shown in figure 15. A description of the steps shown in the flow chart follows:

1. If NSTREM is less than or equal to zero, then no stream reaches are active during the current stress period.

2. Repeat steps 3 through 20 for each reach in the ISTRM list.

3. Determine the column, row, and layer of the cell containing the reach.

4. If the cell is external to the active cells in the simulation, bypass processing on this reach and go on to the next reach.

5. Determine segment number (ISTSG) and reach number (NREACH).

6. IF NREACH equals one then set stream inflow to the reach (FLOWIN) equal to the segment inflow value.

7. If NREACH equals one and ISTSG is greater than one, set ARTRIB (ISTSG-1) equal to the outflow from the last reach in the previous segment.

8. If the segment is a diversion from an upstream segment, IDIVAR (ISTSG) is greater than zero, calculate the flow out of the upstream segment including the amount that is diverted. If more water is to be diverted than is available in the stream, set the amount of flow to be diverted to zero.

9. If flow in the first reach in a segment is negative, as specified in the input data set, then reset FLOWIN equal to zero, sum the outflow from the specified tributary segments in the ITRBAR list and add the sum to FLOWIN.

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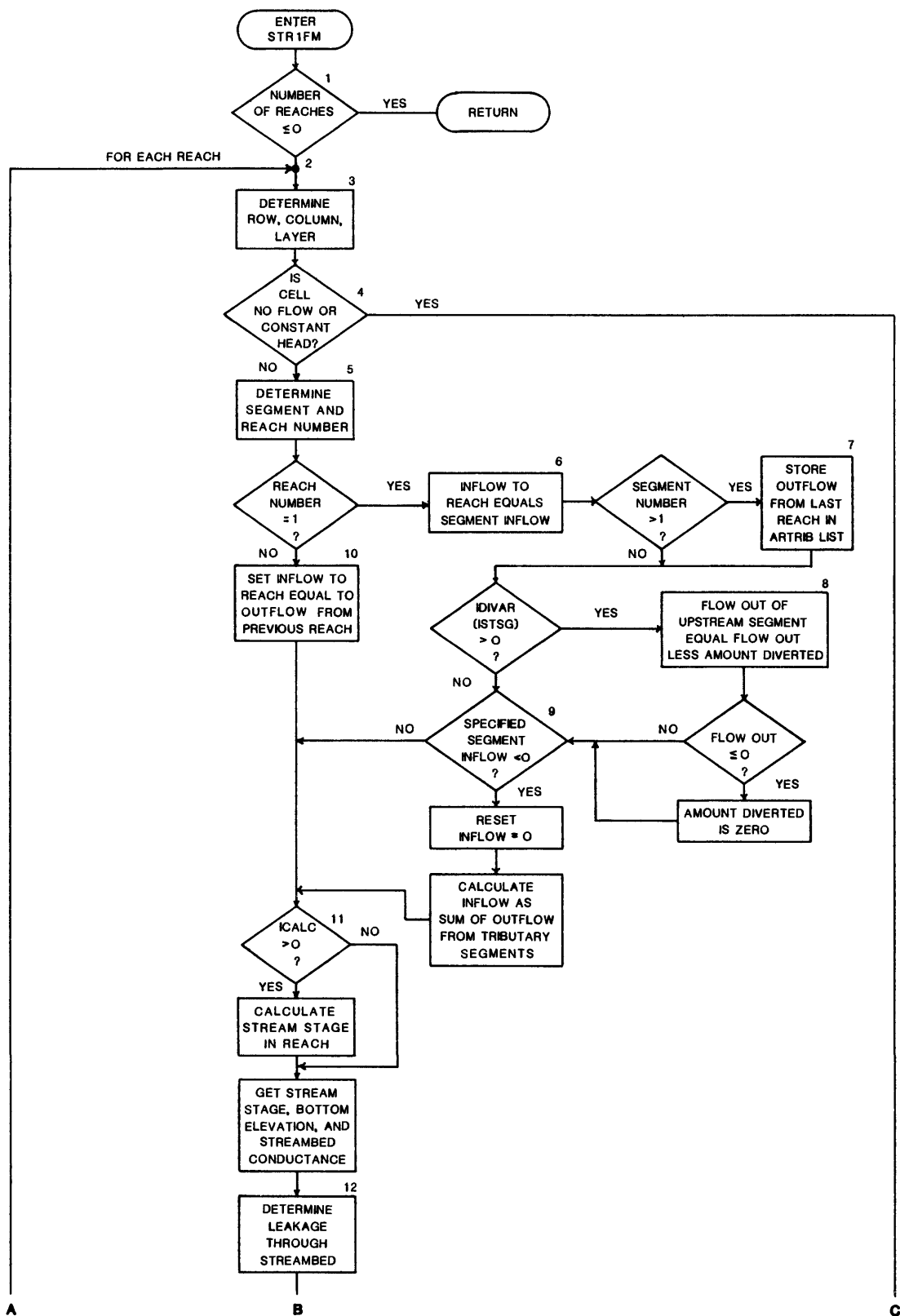
FIGURE 15.--Generalized flow chart of module STR1FM. Variable names are defined in section 'List of variables for module STR1FM.'

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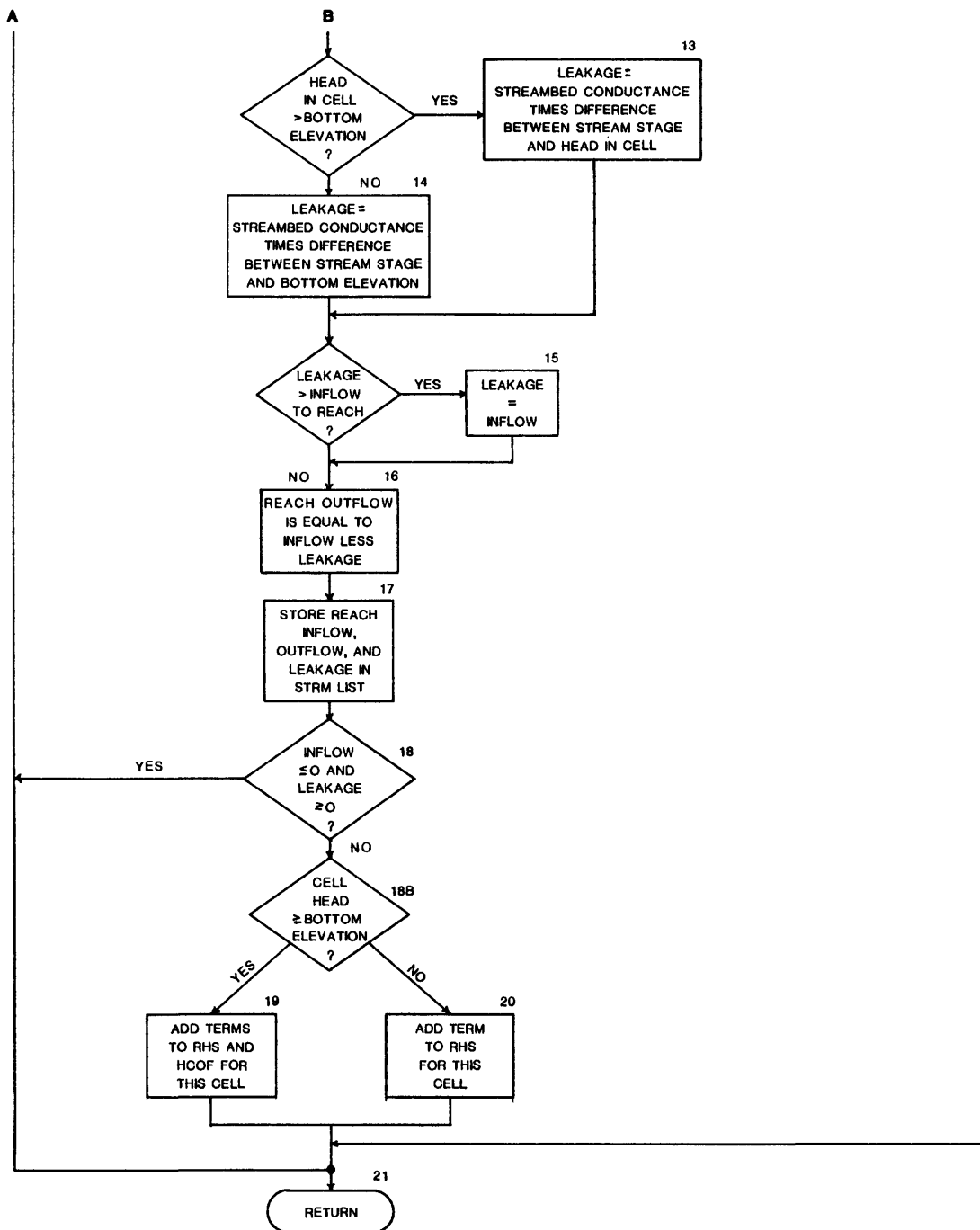
Figure 15.--(concluded)

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10. If NREACH is greater than one, set the flow into the reach equal to the outflow from the adjacent upstream reach (NREACH-1).

11. If ICALC is greater than zero, then calculate stream stage by first calculating the depth then adding the value to top of streambed.

12. Determine leakage (FLOBOT) through streambed for each reach.

13. If the head in model cell (H) is greater than the elevation of bottom of streambed (SBOT), then FLOBOT is equal to streambed conductance (CSTR) times the difference between stream stage and head in model cell [CSTR*(HSTR-H)].

14. If H for the cell is less than or equal to SBOT, then FLOBOT is equal to CSTR times the difference in the elevations between HSTR and SBOT [CSTR*(HSTR-SBOT)].

15. If leakage through the streambed (FLOBOT) is greater than streamflow into the reach (FLOWIN), set FLOBOT equal to FLOWIN.

16. Streamflow out of each reach (FLOWOT) is equal to FLOWIN minus FLOBOT.

17. Store for each reach FLOWIN, FLOWOT, and FLOBOT in the STRM list.

18. If FLOWIN is less than or equal to zero and FLOBOT greater than or equal to zero return to step 3, otherwise determine which accumulators to add to the finite-difference equation.

19. If head in model cell (H) is greater than elevation of bottom of streambed (SBOT), then add the term [-CSTR*HSTR] to the accumulator RHS and the term [-CSTR] to the accumulator HCOF.

20. If head in model cell (H) is less than or equal to SBOT, then add the term [-CSTR*(HSTR-SBOT) to the accumulator RHS. Nothing is added to HCOF.

21. RETURN to MAIN program.

```
       SUBROUTINE STR1FM(NSTREM,STRM,ISTRM,HNEW,HCOF,RHS,IBOUND,MXSTRM,
      1                NCOL,NROW,NLAY,IOUT,NSS,ITRBAR,NTRIB,ARTRIB,
      2                IDIVAR,ICALC,CONST)
C                                                                        C
C-----VERSION   1 23OCT1987 STR1FM                                       C
C     ****************************************************************C
C     ADD STREAM TERMS TO RHS AND HCOF IF FLOW OCCURS IN MODEL CELL     C
C     ****************************************************************C
C                                                                        C
C     SPECIFICATIONS:                                                    C
C     ----------------------------------------------------------------C
C                                                                        C
       DOUBLE PRECISION HNEW
       DIMENSION STRM(11,MXSTRM),ISTRM(5,MXSTRM),HNEW(NCOL,NROW,NLAY),
      1           HCOF(NCOL,NROW,NLAY),RHS(NCOL,NROW,NLAY),
      2           IBOUND(NCOL,NROW,NLAY),ITRBAR(NSS,NTRIB),ARTRIB(NSS),
      3           IDIVAR(NSS)
C     ----------------------------------------------------------------C
C                                                                        C
C1------IF NSTREM<=0 THERE ARE NO STREAMS. RETURN.                       C
       IF(NSTREM.LE.0)RETURN
C                                                                        C
C2------PROCESS EACH CELL IN THE STREAM LIST.                            C
C                                                                        C
C3------DETERMINE LAYER, ROW, COLUMN OF EACH REACH.                      C
       DO 500 L=1,NSTREM
       LL=L-1
       IL=ISTRM(1,L)
       IR=ISTRM(2,L)
       IC=ISTRM(3,L)
C                                                                        C
C4------DETERMINE IF CELL IS OUTSIDE OF MODEL BOUNDARIES.                C
       IF(IBOUND(IC,IR,IL).LE.0)GO TO 500
C                                                                        C
C5------DETERMINE SEGMENT AND REACH NUMBER.                              C
       ISTSG=ISTRM(4,L)
       NREACH=ISTRM(5,L)
C                                                                        C
C6------SET FLOWIN EQUAL TO SEGMENT INFLOW IF FIRST REACH.               C
       IF(NREACH.GT.1) GO TO 200
       FLOWIN=STRM(1,L)
C                                                                        C
C7------STORE OUTFLOW FROM PREVIOUS SEGMENT IN ARTRIB IF SEGMENT >1.     C
       IF(ISTSG.GT.1) IFLG = ISTRM(4,LL)
       IF(ISTSG.GT.1)  ARTRIB(IFLG)=STRM(9,LL)
C                                                                        C
C8------IF SEGMENT IS A DIVERSION, COMPUTE FLOW OUT OF UPSTREAM REACH. C
       IF(IDIVAR(ISTSG).LE.0) GO TO 50
       NDFLG=IDIVAR(ISTSG)
       DUM=ARTRIB(NDFLG)-FLOWIN
```

```
      IF(DUM.GE.0.0) ARTRIB(NDFLG)=DUM
      IF(DUM.GE.0.0) GO TO 50
      FLOWIN=0.
   50 IF(FLOWIN.GE.0.0) GO TO 300
C                                                                      C
C9-----SUM TRIBUTARY OUTFLOW AND USE AS INFLOW INTO DOWNSTREAM SEGMENT.C
      FLOWIN =0.
      DO 100 ITRIB=1,NTRIB
      INODE=ITRBAR(ISTSG,ITRIB)
      IF(INODE.LE.0) GO TO 100
      FLOWIN=FLOWIN+ARTRIB(INODE)
  100 CONTINUE
C                                                                      C
C10-----IF REACH >1, SET INFLOW EQUAL TO OUTFLOW FROM UPSTREAM REACH.  C
  200 IF(NREACH.GT.1) FLOWIN=STRM(9,LL)
C                                                                      C
C11----COMPUTE STREAM STAGE IN REACH IF ICALC IS GREATER THAN 1.       C
  300 IF(ICALC.LE.0) GO TO 310
      XNUM=((FLOWIN+STRM(9,L))/2.0)*STRM(8,L)
      DNOM=CONST*STRM(6,L)*(SQRT(STRM(7,L)))
      DEPTH=(XNUM/DNOM)**0.6
      IF(DEPTH.LE.0.) DEPTH=0.
      STRM(2,L)=DEPTH+STRM(5,L)
  310 HSTR=STRM(2,L)
C                                                                      C
C12----DETERMINE LEAKAGE THROUGH STREAMBED.                            C
      IF(FLOWIN.LE.0.) HSTR=STRM(5,L)
      CSTR=STRM(3,L)
      SBOT=STRM(4,L)
      H=HNEW(IC,IR,IL)
      T=HSTR-SBOT
C                                                                      C
C13----COMPUTE LEAKAGE AS A FUNCTION OF STREAM STAGE AMD HEAD IN CELL. C
      FLOBOT=CSTR*(HSTR-H)
C                                                                      C
C14----RECOMPUTE LEAKAGE IF HEAD IN CELL IS BELOW STREAMBED BOTTOM.    C
      IQFLG=0
      IF(H.GT.SBOT) GO TO 312
      IQFLG=1
      FLOBOT=CSTR*T
C                                                                      C
C15----SET LEAKAGE EQUAL TO STREAM INFLOW IF LEAKAGE MORE THAN INFLOW. C
  312 IF(FLOBOT.LE.FLOWIN) GO TO 320
      IQFLG=1
      FLOBOT=FLOWIN
C                                                                      C
C16-----STREAMFLOW OUT EQUALS STREAMFLOW IN MINUS LEAKAGE.             C
  320 FLOWOT=FLOWIN-FLOBOT
      IF((ISTSG.GT.1).AND.(NREACH.EQ.1)) STRM(9,LL)=ARTRIB(IFLG)
C                                                                      C
C17----STORE STREAM INFLOW, OUTFLOW AND LEAKAGE FOR EACH REACH.        C
      STRM(9,L)=FLOWOT
      STRM(10,L)=FLOWIN
      STRM(11,L)=FLOBOT
```

```
C                                                                             C
C18----RETURN TO STEP 3 IF STREAM INFLOW IS LESS THAN OR EQUAL TO ZERO C
C        AND LEAKAGE IS GREATER THAN OR EQUAL TO ZERO.                 C
      IF((FLOWIN.LE.0.0).AND.(FLOBOT.GE.0.0)) GO TO 500
C                                                                             C
C19------IF HEAD > BOTTOM THEN ADD TERMS TO RHS AND HCOF.              C
      IF(IQFLG.GT.0) GO TO 400
      RHS(IC,IR,IL)=RHS(IC,IR,IL)-CSTR*HSTR
      HCOF(IC,IR,IL)=HCOF(IC,IR,IL)-CSTR
      GO TO 500
C                                                                             C
C20------IF HEAD < BOTTOM THEN ADD TERM ONLY TO RHS.                   C
  400 RHS(IC,IR,IL)=RHS(IC,IR,IL)-FLOBOT
  500 CONTINUE
C                                                                             C
C21-----RETURN.                                                        C
      RETURN
      END
```

List of Variables for Module STR1FM

Variable	Range	Definition
ARTRIB	Package	DIMENSION(NSS), For each segment: contains the streamflow out of last reach in each stream segment.
CONST	Package	A constant used in calculating stream stage in reaches. Specified only when ICALC is greater than zero. A value of 1.486 is used for units of cubic feet per second and a value of 1.0 is used for units of cubic meters per second. The value must be multiplied by 86,400 when days are used as the time unit.
CSTR	Module	Streambed hydraulic conductance.
DEPTH	Module	Depth of water in reach. The value is added to top of streambed to obtain the stream stage.
DNOM	Module	Denominator of the equation used to calculate depth of water in a reach.
DUM	Module	Amount of flow from upstream segment from which water is diverted.
FLOBOT	Module	Leakage into or out of a model cell through the streambed.
FLOWIN	Module	Streamflow into reach. If streamflow into the first reach of a segment is negative, then FLOWIN is the sum of streamflow out of the last reach in each specified tributary segment.
FLOWOT	Module	Streamflow out of reach.
H	Module	Head in model cell (HNEW).
HCOF	Global	DIMENSION (NCOL,NROW,NLAY), Coefficient of the cell (J,I,K) in the finite-difference equation.
HNEW	Global	DIMENSION (NCOL,NROW,NLAY), Most recent estimate of head in each cell. HNEW changes at each iteration.
HSTR	Module	Stream stage in reach.

IBOUND	Global	DIMENSION (NCOL,NROW,NLAY), Status of each cell. <0, constant-head cell. =0, inactive cell. >0, variable-head cell.
IC	Module	Column number of cell containing reach.
ICALC	Package	Flag. >0, stream stage in reaches will be calculated. ≤0, stream stage in reaches will not be calculated.
IDIVAR	Package	DIMENSION (NSS), For each segment: upstream segment number from which water is to be diverted.
IFLG	Module	Number of previous segment.
IL	Module	Layer number of cell containing reach.
INODE	Module	Number of a tributary segment.
IOUT	Global	Primary unit number for all printed output.
IQFLG	Module	Flag used for assigning proper terms to RHS and HCOF. 0, head in model cell is greater than streambed bottom. 1, head in model cell is less than or equal to streambed bottom.
IR	Module	Row number of cell containing reach.
ISTRM	Package	DIMENSION(5,MXSTRM), For each reach: layer, row, column, segment number, and reach number.
ISTSG	Module	Segment number of cell containing reach.
ITRBAR	Package	DIMENSION (NSS,NTRIB), For each segment: segment numbers of each tributary segment. A zero is assigned if no segments are tributary to a given segment.
ITRIB	Module	Index for the number of tributary segments.
L	Module	Index for current reach.
LL	Module	Index for previous reach.
MXSTRM	Package	Maximum number of stream reaches.

NCOL	Global	Number of columns in grid.
NDFLG	Module	Number of segments from which water is diverted.
NLAY	Global	Number of layers in grid.
NREACH	Module	Number of reach in segment.
NROW	Global	Number of rows in grid.
NSS	Package	Maximum number of segments.
NSTREM	Package	Number of stream reaches active during current stress period.
NTRIB	Package	Maximum number of tributary segments that join one downstream segment.
RHS	Global	DIMENSION (NCOL,NROW,NLAY), Right side of the finite-difference equation. RHS is an accumulation of terms from several different packages.
SBOT	Module	Elevation of streambed bottom.
STRM	Package	DIMENSION (11,MXSTRM), For each reach: (1) segment inflow, (2) stream stage, (3) streambed conductance, (4) streambed bottom and (5) top elevations, (6) stream width, (7) channel slope, (8) Manning's roughness coefficient, (9) streamflow out of each reach, (10) streamflow into each reach, and (11) leakage through the streambed in each reach.
T	Module	Difference between stream stage (HSTR) and elevation of the streambed bottom (SBOT).
XNUM	Module	Numerator of the equation used to calculate depth of water in a reach.

Module STR1BD

Module STR1BD calculates the rates and volumes of stream leakage into and out of the model cells and calculates streamflow into and out of each reach. It then saves results onto unformated disk files or prints results to a different file.

Narrative for Module STR1BD

The module STR1BD calculates rates and volumes transferred between the aquifer and streams and in addition, calculates the final stream inflow and outflow each time step for each reach. A generalized flow chart of the module is shown in figure 16. A description of the steps shown in the flow chart follows:

1. Initialize the cell-by-cell flow-term flag (IBD) and the rate accumulators (RATIN and RATOUT).

2. If no reaches are specified (NSTREM<or=0), skip down to step 25 and put zeros into the budget terms for streams.

3. Test to determine if leakage to and from the streams for each reach is to be saved on the disk. They will not be saved if either of the following conditions are true: (1) If this is not the proper time step (ICBCFL=0 in the OUTPUT package) or (2) if the term ISTCB1 is less than or equal to zero. If leakage between each stream reach and corresponding model cell is to be saved on disk, then the flag IBD is set equal to one and the buffer (BUFF) is cleared so leakage can be accumulated.

4. Repeat steps 5 through 23 for each reach in the ISTRM list accumulating leakage between each reach and corresponding model cell, and computing streamflows into and out of each reach.

5. Determine column, row, and layer of the cell containing the reach.

6. If the cell is external to active cells in the simulation, bypass processing for this reach and go to the next reach.

7. Determine the segment number (ISTSG) and reach number (NREACH).

8. If NREACH equals one, then set stream inflow to the reach (FLOWIN) equal to the segment inflow value.

9. If NREACH equals one and ISTSG is greater than one, set ARTRIB (ISTSG-1) equal to the outflow from the last reach in the previous segment.

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10. If the segment is a diversion from an upstream segment, IDIVAR (ISTSG) is greater than zero, calculate the flow out of the upstream segment including the amount that is diverted. If more water is to be diverted than is available in the stream, set the amount of flow to be diverted to zero.

11. If flow in the first reach in a segment is negative, as specified in the input data set, then reset FLOWIN to zero and sum the outflow from the specified tributary segments in the ITRBAR list and add the sum to FLOWIN.

12. If NREACH is greater than one, set the flow into the reach equal to the outflow from the adjacent upstream reach (NREACH-1).

13. If ICALC is greater than zero, then calculate the stream stage by first calculating the depth then adding the value to the top of the streambed.

14. Determine the leakage (FLOBOT) through the streambed for each reach.

15. If the head in the model cell (H) is greater than the elevation of bottom of the streambed (SBOT), then FLOBOT is equal to streambed conductance (CSTR) times the difference between stream stage in reach and head in model cell [CSTR*(HSTR-H)].

16. If H in the cell is less than or equal to SBOT, then FLOBOT is equal to CSTR times the difference in elevations between HSTR and SBOT [CSTR*(HSTR-SBOT)].

17. If leakage through the streambed (FLOBOT) is greater than streamflow into the reach (FLOWIN), set FLOBOT equal to FLOWIN.

18. Set streamflow out of reach (FLOWOT) equal to FLOWIN minus FLOBOT.

19. Record FLOWIN, FLOWOT, and FLOBOT in the STRM list.

20. If the leakage values are to be saved on disk (IBD=1), add FLOBOT to the buffer (BUFF).

21. Determine if flow is into or out of model cell.

22. If FLOBOT is negative, subtract it from RATOUT.

23. If FLOBOT is positive, add it to RATIN.

24. If leakage between reach and corresponding model cell is to be saved on disk (IBD=1), call module UBUDSV to save the buffer (BUFF) onto a disk file. (Module UBUDSV is part of the program by McDonald and Harbaugh, 1988.)

25. Move RATIN and RATOUT into the VBVL array for printing by BAS1OT. Add RATIN and RATOUT multiplied by the time-step length to the volume accumulators in VBVL for printing by BAS1OT. Move the stream

budget term labels to VBNM for printing by BAS1OT. (Module BAS1OT is part of the Basic Package in McDonald and Harbaugh, 1988.)

26. Increase the budget-term counter (MSUM) by one.

27. Reset IBD to 0.

28. Determine if streamflows out of each reach are to be saved on disk. Values will not be saved if either of the following conditions are true: (1) This is not the proper time step (ICBCFL=0) or (2) the variable ISTCB2 is less than or equal to zero. If streamflows out of each reach are to be saved, set IBD=1 and initialize the buffer (BUFF) to zero.

29. If IBD=1, read into buffer the streamflow out of each reach and then call module UBUDSV to read the buffer (BUFF) onto the disk.

30. If ISTCB1 is less than zero, IPTFLG equals zero, and ICBCFL is greater than zero, print leakage and streamflows into and out of each reach.

31. RETURN to MAIN program.
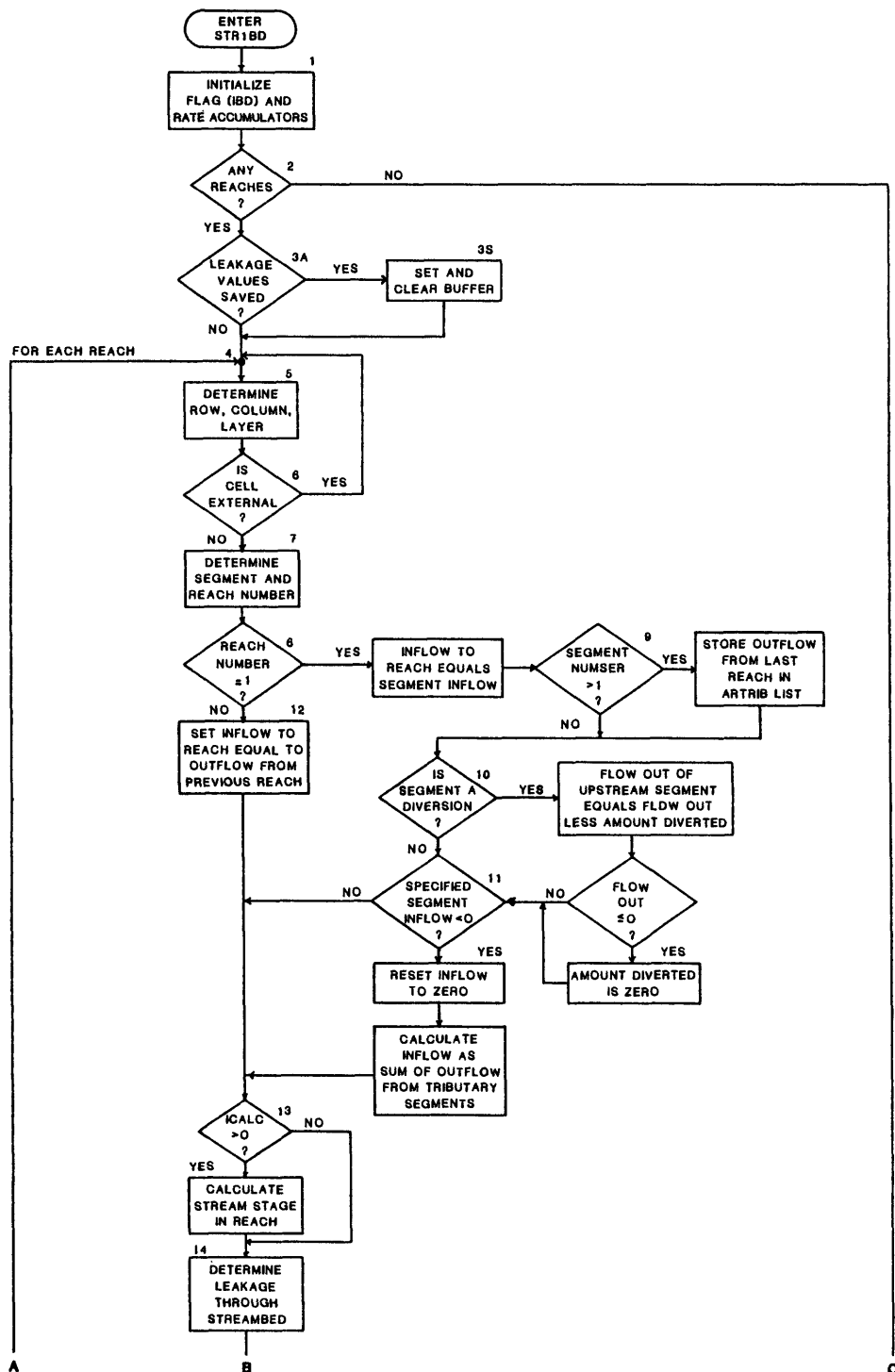
Figure 16.--Generalized flow chart of Module STR1BD. Variable names are defined in section "List of variables for module STR1BD."

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Figure 16.--(concluded)

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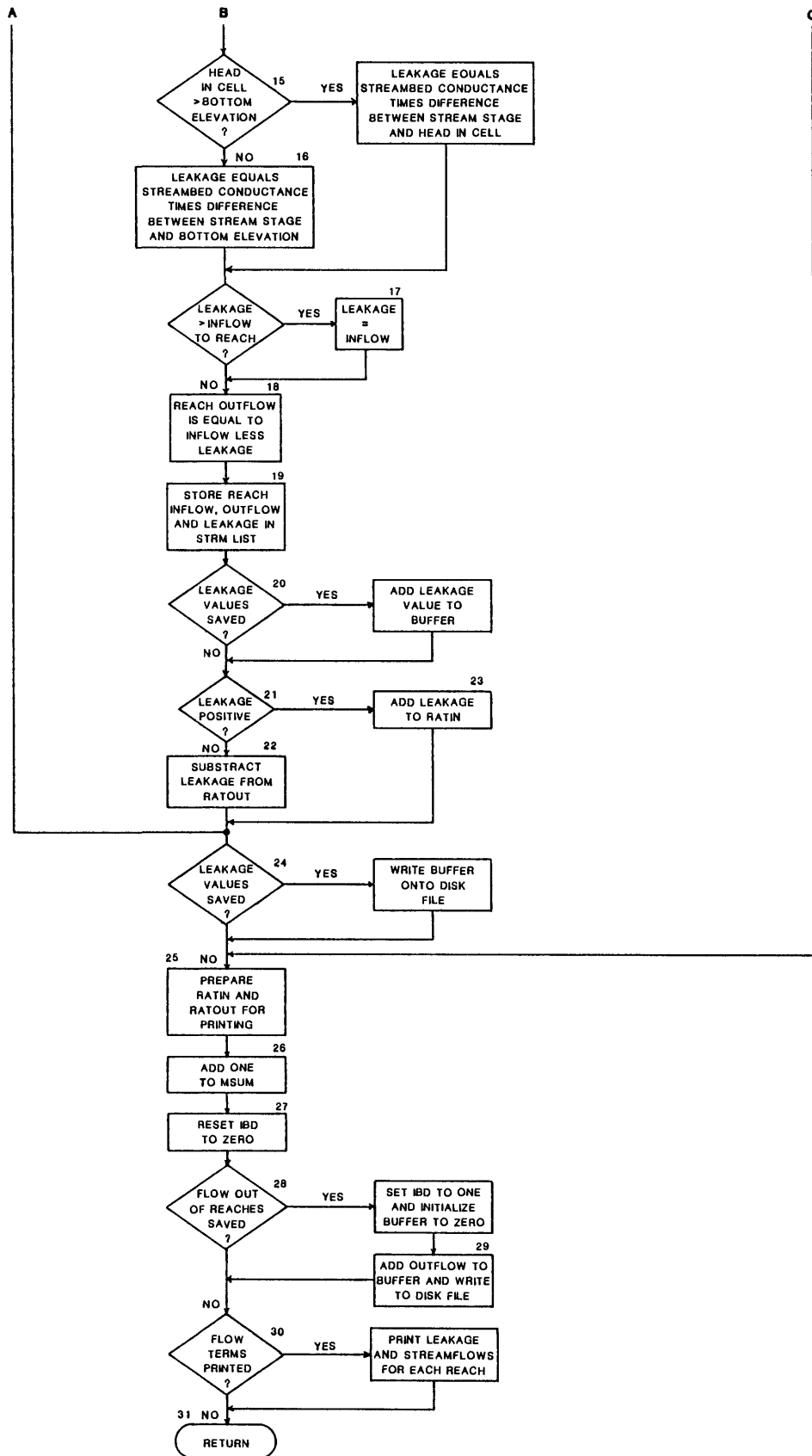
```
      SUBROUTINE STR1BD(NSTREM,STRM,ISTRM,IBOUND,MXSTRM,HNEW,NCOL,NROW,
     1    NLAY,DELT,VBVL,VBNM,MSUM,KSTP,KPER,ISTCB1,ISTCB2,ICBCFL,
     2    BUFF,IOUT,NTRIB,NSS,ARTRIB,ITRBAR,IDIVAR,ICALC,CONST,IPTFLG)
C-----VERSION 1  23OCT1987 STR1BD                                       C
C     ***********************************************************************C
C     CALCULATE VOLUMETRIC BUDGET FOR STREAMS                           C
C     ***********************************************************************C
C                                                                       C
C     SPECIFICATIONS:                                                   C
C     -------------------------------------------------------------------C
      CHARACTER*4 VBNM,TEXT,STRTXT
      DOUBLE PRECISION HNEW
      DIMENSION STRM(11,MXSTRM),ISTRM(5,MXSTRM),IBOUND(NCOL,NROW,NLAY),
     1          HNEW(NCOL,NROW,NLAY),VBVL(4,20),VBNM(4,20),
     2          BUFF(NCOL,NROW,NLAY),ARTRIB(NSS),ITRBAR(NSS,NTRIB),
     3          IDIVAR(NSS)
      DIMENSION TEXT(4),STRTXT(4)
      DATA TEXT(1),TEXT(2),TEXT(3),TEXT(4) /'  ST','REAM',' LEA','KAGE'/
      DATA STRTXT(1),STRTXT(2),STRTXT(3),STRTXT(4) /'STRE','AM F',
     1                                              'LOW ','OUT '/
C     -------------------------------------------------------------------C
C                                                                       C
C1------SET IBD=1 IF BUDGET TERMS SHOULD BE SAVED ON DISK.              C
      IBD=0
      RATIN = 0.
      RATOUT = 0.
C                                                                       C
C2------IF NO REACHES, KEEP ZEROS IN ACCUMULATORS.                      C
      IF(NSTREM.EQ.0) GO TO 600
C                                                                       C
C3A-----TEST TO SEE IF CELL-BY-CELL TERMS ARE NEEDED.                   C
      IF((ICBCFL.EQ.0).OR.(ISTCB1.LE.0)) GO TO 10
C                                                                       C
C3B-----CELL-BY-CELL TERMS ARE NEEDED, SET IBD AND CLEAR BUFFER.        C
      IBD = 1
      DO 5 IL=1,NLAY
      DO 5 IR=1,NROW
      DO 5 IC=1,NCOL
      BUFF(IC,IR,IL)=0.
    5 CONTINUE
C                                                                       C
C4------IF THERE ARE STREAMS THEN ACCUMULATE LEAKAGE TO OR FROM THEM.   C
   10 DO 500 L=1,NSTREM
      LL=L-1
C                                                                       C
C5---DETERMINE REACH LOCATION.                                          C
      IL=ISTRM(1,L)
      IR=ISTRM(2,L)
      IC=ISTRM(3,L)
C                                                                       C
C6---IF CELL IS EXTERNAL SKIP CALCULATIONS.                             C
```

```
      IF(IBOUND(IC,IR,IL).LE.0)GO TO 500
C                                                                      C
C7------DETERMINE SEGMENT AND REACH NUMBER.                            C
      ISTSG=ISTRM(4,L)
      NREACH=ISTRM(5,L)
      IF(NREACH.GT.1) GO TO 200
C                                                                      C
C8------SET FLOWIN EQUAL TO SEGMENT INFLOW IF FIRST REACH.             C
      FLOWIN=STRM(1,L)
      IF(ISTSG.GT.1) IFLG = ISTRM(4,LL)
C                                                                      C
C9------STORE OUTFLOW FROM PREVIOUS SEGMENT IN ARTRIB IF SEGMENT >1.    C
      IF(ISTSG.GT.1)  ARTRIB(IFLG)=STRM(9,LL)
C                                                                      C
C10--IF SEGMENT IS A DIVERSION, COMPUTE FLOW OUT OF UPSTREAM SEGMENT.   C
      IF(IDIVAR(ISTSG).LE.0) GO TO  50
      NDFLG=IDIVAR(ISTSG)
      DUM=ARTRIB(NDFLG)-FLOWIN
      IF(DUM.GE.0.0) ARTRIB(NDFLG)=DUM
      IF(DUM.GE.0.0) GO TO  50
      FLOWIN=0.
   50 IF(FLOWIN.GE.0.0) GO TO 300
C                                                                      C
C11--SUM TRIBUTARY OUTFLOW AND USE AS INFLOW INTO DOWNSTREAM SEGMENT.   C
      FLOWIN =0.
      DO 100 ITRIB=1,NTRIB
      INODE=ITRBAR(ISTSG,ITRIB)
      IF(INODE.LE.0) GO TO 100
      FLOWIN=FLOWIN+ARTRIB(INODE)
  100 CONTINUE
C                                                                      C
C12-----IF REACH >1, SET INFLOW EQUAL TO OUTFLOW FROM UPSTREAM REACH.   C
  200 IF(NREACH.GT.1) FLOWIN=STRM(9,LL)
C                                                                      C
C13----COMPUTE STREAM STAGE IN REACH IF ICALC > 1.                      C
  300 IF(ICALC.LE.0) GO TO 310
      XNUM=((FLOWIN+STRM(9,L))/2.0)*STRM(8,L)
      DNOM=CONST*STRM(6,L)*(SQRT(STRM(7,L)))
      DEPTH=(XNUM/DNOM)**0.6
      IF((DEPTH).LE.0) DEPTH=0.
      STRM(2,L)=DEPTH+STRM(5,L)
  310 HSTR=STRM(2,L)
C                                                                      C
C14----DETERMINE LEAKAGE THROUGH STREAMBED.                             C
      IF(FLOWIN.LE.0.0) HSTR=STRM(5,L)
      CSTR=STRM(3,L)
      SBOT=STRM(4,L)
      H=HNEW(IC,IR,IL)
      T=HSTR-SBOT
C                                                                      C
C15----COMPUTE LEAKAGE AS A FUNCTION OF STREAM STAGE AND HEAD IN CELL.   C
      FLOBOT=CSTR*(HSTR-H)
C                                                                      C
C16----RECOMPUTE LEAKAGE IF HEAD IN CELL IS BELOW STREAMBED BOTTOM.      C
      IF(H.GT.SBOT) GO TO 312
```

```
      FLOBOT=CSTR*T
C                                                                          C
C17----SET LEAKAGE EQUAL TO STREAM INFLOW IF LEAKAGE MORE THAN INFLOW. C
  312 IF(FLOBOT.LE.FLOWIN) GO TO 320
      FLOBOT=FLOWIN
C                                                                          C
C18----STREAMFLOW OUT EQUALS STREAMFLOW IN MINUS LEAKAGE.              C
  320 FLOWOT=FLOWIN-FLOBOT
      IF((ISTSG.GT.1).AND.(NREACH.EQ.1)) STRM(9,LL)=ARTRIB(IFLG)
C                                                                          C
C19----STORE STREAM INFLOW, OUTFLOW AND LEAKAGE FOR EACH REACH.        C
      STRM(9,L)=FLOWOT
      STRM(10,L)=FLOWIN
      STRM(11,L)=FLOBOT
C                                                                          C
C20----IF LEAKAGE FROM STREAMS IS TO BE SAVED THEN ADD RATE TO BUFFER. C
      IF(IBD.EQ.1) BUFF(IC,IR,IL)=BUFF(IC,IR,IL)+FLOBOT
C                                                                          C
C21----DETERMINE IF FLOW IS INTO OR OUT OF MODEL CELL.                 C
C        SKIP ESTIMATE OF LEAKAGE FROM STREAM IF LEAKAGE IS ZERO.      C
      IF(FLOBOT)494,500,496
C                                                                          C
C22-----SUBTRACT FLOW RATE FROM RATOUT IF AQUIFER DISCHARGES TO STREAM.C
  494 RATOUT=RATOUT-FLOBOT
      GO TO 500
C                                                                          C
C23-----ADD FLOW RATE TO RATIN IF STREAM DISCHARGES TO AQUIFER.        C
  496 RATIN=RATIN+FLOBOT
  500 CONTINUE
C                                                                          C
C24-----IF BUDGET TERMS WILL BE SAVED THEN WRITE TO DISK.              C
      IF(IBD.EQ.1) CALL UBUDSV(KSTP,KPER,TEXT,ISTCB1,BUFF,NCOL,NROW,
     1                          NLAY,IOUT)
C                                                                          C
C25A-----MOVE RATES INTO VBVL FOR PRINTING BY MODULE BAS_OT.           C
  600 VBVL(3,MSUM)=RATIN
      VBVL(4,MSUM)=RATOUT
C                                                                          C
C25B-----MOVE PRODUCT OF RATE AND TIME STEP INTO VBVL ACCUMULATORS.    C
      VBVL(1,MSUM)=VBVL(1,MSUM)+RATIN*DELT
      VBVL(2,MSUM)=VBVL(2,MSUM)+RATOUT*DELT
C                                                                          C
C25C-----MOVE BUDGET TERM LABELS INTO VBNM FOR PRINTING BY BAS_OT.     C
      VBNM(1,MSUM)=TEXT(1)
      VBNM(2,MSUM)=TEXT(2)
      VBNM(3,MSUM)=TEXT(3)
      VBNM(4,MSUM)=TEXT(4)
C                                                                          C
C26-----INCREASE BUDGET TERM COUNTER BY ONE.                          C
      MSUM=MSUM+1
C                                                                          C
C27-----RESET IBD COUNTER TO ZERO.                                    C
      IBD=0
C28----IF STREAM OUTFLOW FROM EACH REACH IS TO BE STORED IN ON DISK    C
C        THEN STORE OUTFLOW RATES INTO BUFFER.                         C
```

```
      IF((ICBCFL.EQ.O).OR.(ISTCB2.LE.O)) GO TO 625
      IBD = 1
      DO 605 IL=1,NLAY
      DO 605 IR=1,NROW
      DO 605 IC=1,NCOL
  605 BUFF(IC,IR,IL)=0.
C                                                             C
C29-----SAVE STREAMFLOWS OUT OF EACH REACH ON DISK.          C
      DO 615 L=1,NSTREM
      IC=ISTRM(3,L)
      IR=ISTRM(2,L)
      IL=ISTRM(1,L)
      IF(IBOUND(IC,IR,IL).LE.0) GO TO 615
      BUFF(IC,IR,IL)=BUFF(IC,IR,IL)+STRM(9,L)
  615 CONTINUE
      CALL UBUDSV(KSTP,KPER,STRTXT,ISTCB2,BUFF,NCOL,NROW,NLAY,IOUT)
C                                                             C
C30-----PRINT STREAMFLOW RATES AND LEAKAGE FOR EACH REACH.    C
  625 IF((ISTCB1.GE.0).OR.(ICBCFL.LE.0)) GO TO 800
      IF(IPTFLG.GT.0) GO TO 800
      IF(ICALC.GT.0) GO TO 700
      WRITE(IOUT,650)
  650 FORMAT(1H0,12X,'LAYER',6X,'ROW',5X,'COLUMN',5X,'STREAM',4X,
     1'REACH',6X,'FLOW INTO',4X,'FLOW INTO',6X,'FLOW OUT OF'/43X,
     2       'NUMBER',3X,'NUMBER',4X,'STREAM REACH',4X,'AQUIFER',
     3       6X,'STREAM REACH'//)
      DO 690 L=1,NSTREM
      IL=ISTRM(1,L)
      IR=ISTRM(2,L)
      IC=ISTRM(3,L)
      WRITE(IOUT,675)IL,IR,IC,ISTRM(4,L),ISTRM(5,L),
     1       STRM(10,L),STRM(11,L),STRM(9,L)
  675 FORMAT(1X,5X,5I10,8X,G9.3,5X,G9.3,8X,G9.3)
  690 CONTINUE
      GO TO 800
  700 WRITE(IOUT,710)
  710 FORMAT(1H0,12X,'LAYER',6X,'ROW',5X,'COLUMN',5X,'STREAM',4X,
     1'REACH',6X,'FLOW INTO',4X,'FLOW INTO',6X,'FLOW OUT OF',5X,
     2'HEAD IN'/43X,       'NUMBER',3X,'NUMBER',4X,'STREAM REACH',
     3 4X,'AQUIFER',6X,'STREAM REACH',5X,'STREAM'//)
      DO 750 L=1,NSTREM
      IL=ISTRM(1,L)
      IR=ISTRM(2,L)
      IC=ISTRM(3,L)
      WRITE(IOUT,775)IL,IR,IC,ISTRM(4,L),ISTRM(5,L),
     1       STRM(10,L),STRM(11,L),STRM(9,L),STRM(2,L)
  775 FORMAT(1X,5X,5I10,8X,G9.3,5X,G9.3,7X,G9.3,4X,F9.2)
  750 CONTINUE
  800 CONTINUE
C                                                             C
C31-----RETURN.                                               C
      RETURN
      END
```

List of Variables for STR1BD

Variable	Range	Definition
ARTRIB	Package	DIMENSION (NSS), For each segment: contains the streamflow out of last reach in each stream segment.
BUFF	Global	DIMENSION (NCOL,NROW,NLAY), Buffer used to accumulate information before sending it to a disk file.
CONST	Package	A constant used in calculating stream stage in reaches. Specified only when ICALC is greater than zero. A value of 1.486 is used for units of cubic feet per second and a value of 1.0 is used for units of cubic meters per second. The constant is multiplied by 86,400 when days are used as the time unit.
CSTR	Module	Streambed hydraulic conductance.
DELT	Global	Length of current time step.
DEPTH	Module	Depth of water in reach. The value is added to top of streambed to obtain the stream stage.
DNOM	Module	Denominator of the equation used to calculate depth of water in a reach.
DUM	Module	Amount of flow from segment from which water is diverted.
FLOBOT	Module	Leakage into or out of model cell through the streambed.
FLOWIN	Module	Streamflow into reach. If, streamflow into the first reach of a segment is negative, then FLOWIN is the sum of streamflow out of the last reach in each specified tributary segment.
FLOWOT	Module	Streamflow out of a reach.
H	Module	Head in the model cell (HNEW).
HNEW	Global	DIMENSION (NCOL,NROW,NLAY), Most recent estimate of head in each cell. HNEW changes at each iteration.

HSTR	Module	Stream stage in reach.
IBD	Module	Flag. =0, flow terms for each reach will not be saved on a disk file. =1, flow terms for each reach will be saved on a disk file.
IBOUND	Global	DIMENSION (NCOL,NROW,NLAY), Status of each cell. <0, constant-head cell. =0, inactive cell. >0, variable-head cell.
ICBCFL	Global	Flag used to specify the frequency of recording or printing of results. =0, cell-by-cell flow terms will not be recorded or printed for the current time step. (not)=0, cell-by-cell flow terms will be either printed or recorded depending on the values for variables ISTCB1, ISTCB2 or IPTFLG.
IC	Module	Column number of cell containing reach.
ICALC	Package	Flag. >0, stream stage in reaches will be calculated. ≤0, stream stage in reaches will not be calculated.
IDIVAR	Package	DIMENSION (NSS), For each segment: upstream segment number from which water is to be diverted.
IFLG	Module	Number of previous segment.
IL	Module	Layer number of cell containing reach.
INODE	Module	Number of a tributary segment.
IOUT	Global	Primary unit number for all printed output. IOUT = FORTRAN unit number 6.
IPTFLG	Package	Flag to specify printing of results for each stress period. Results may be printed at selected time steps within a stress period depending on the value specified for variable ICBCFL. 0, results will be printed according to the value of ICBCFL. >0, results will not be printed even if ICBCFL is specified.

IR	Module	Row number of cell containing reach.
ISTCB1	Package	Flag and unit number. >0, unit number to which leakage between each reach and corresponding model cell is saved on disk whenever the variable ICBCFL is specified. =0, leakage will not be printed nor recorded. <0, leakage between each stream reach and corresponding model cell will be printed whenever the variables ICBCFL and IPTFLG are specified.
ISTCB2	Package	Flag and unit number. >0, unit number to which streamflow out of each reach will be saved on disk whenever the variable ICBCFL is specified. ≤0, streamflow out of each reach will not be saved on disk.
ISTRM	Package	DIMENSION (5,MXSTRM), For each reach: layer, row, column, segment number, and reach number.
ISTSG	Module	Segment number of cell containing reach.
ITRBAR	Package	DIMENSION (NSS,NTRIB), For each segment: segment numbers of each tributary segment. A zero is assigned if no segments are tributary to a given segment.
ITRIB	Module	Index for the number of tributary segments.
KPER	Global	Stress period counter.
KSTP	Global	Time step counter. Reset at start of each stress period.
L	Module	Index for current reach.
LL	Module	Index for previous reach.
MSUM	Global	Counter for budget entries and labels into VBVL and VBNM.
MXSTRM	Package	Maximum number of stream reaches.
NCOL	Global	Number of columns in grid.
NDFLG	Module	Number of segments from which water is diverted.

NLAY	Global	Number of layers in grid.
NREACH	Module	Number of reach in segment.
NROW	Global	Number of rows in grid.
NSS	Package	Maximum number of stream segments.
NSTREM	Package	Number of stream reaches active during current stress period.
NTRIB	Package	Maximum number of tributary segments that join one downstream segment.
RATIN	Module	Accumulator for the total leakage into the model cells through the streambeds of all reaches.
RATOUT	Module	Accumulator for the total leakage out of the model cells through the streambed of all reaches.
SBOT	Module	Elevation of streambed bottom.
STRM	Package	DIMENSION (11,MXSTRM), For each reach: (1) segment inflow, (2) stream stage, (3) streambed conductance, (4) streambed bottom and (5) top elevations, (6) stream width, (7) channel slope, (8) Manning's roughness coefficient, (9) streamflow out of each reach, (10) streamflow into each reach, and (11) leakage through the streambed in each reach.
STRTXT	Module	Label to be recorded with streamflows out of each reach when the data is saved on a specified unit number.
T	Module	Difference between stream stage (HSTR) and elevation of streambed bottom (SBOT).
TEXT	Module	Label to be recorded with leakage into or out of model cells through the streambed of each reach when data is saved on a specified unit number. The label is also used in the budget table.
VBNM	Global	DIMENSION (4,20), Labels for entries in volumetric budget.

VBVL   Global   DIMENSION (4,20), Entries for the volumetric
                              budget. For flow component N, values in
                              VBVL are:
                              (1,N) volume into the flow field during the
                                    simulation.
                              (2,N) volume out of the flow field during
                                    the simulation.
                              (3,N) rate for current time step into the
                                    flow field.
                              (4,N) rate for current time step out of the
                                    flow field.

XNUM   Module   Numerator of equation used to calculate depth
                              of water in a reach.

```
C      *******************************************************************
C      MAIN CODE FOR MODULAR MODEL --   9/1/87
C           BY MICHAEL G. MCDONALD AND ARLEN W. HARBAUGH
C-----VERSION 1638 24JUL1987 MAIN1
C           MODIFIED BY DAVID E. PRUDIC 23OCT1987  MAINSTREAM
C      *******************************************************************
C
C      SPECIFICATIONS:
C      ------------------------------------------------------------------
       COMMON X(200000)
       COMMON /FLWCOM/LAYCON(80)
       CHARACTER*4 HEADNG,VBNM
       DIMENSION HEADNG(32),VBNM(4,20),VBVL(4,20),IUNIT(24)
       DOUBLE PRECISION DUMMY
       EQUIVALENCE (DUMMY,X(1))
C      ------------------------------------------------------------------
C
C1------SET SIZE OF X ARRAY. REMEMBER TO REDIMENSION X.
       LENX=200000
C
C2------ASSIGN BASIC INPUT UNIT AND PRINTER UNIT.
       INBAS=5
       IOUT=6
C
C3------DEFINE PROBLEM__ROWS,COLUMNS,LAYERS,STRESS PERIODS,PACKAGES
       CALL BAS1DF(ISUM,HEADNG,NPER,ITMUNI,TOTIM,NCOL,NROW,NLAY,
      1            NODES,INBAS,IOUT,IUNIT)
C
C4------ALLOCATE SPACE IN "X" ARRAY.
       CALL BAS1AL(ISUM,LENX,LCHNEW,LCHOLD,LCIBOU,LCCR,LCCC,LCCV,
      1            LCHCOF,LCRHS,LCDELR,LCDELC,LCSTRT,LCBUFF,LCIOFL,
      2            INBAS,ISTRT,NCOL,NROW,NLAY,IOUT)
       IF(IUNIT(1).GT.0) CALL BCF1AL(ISUM,LENX,LCSC1,LCHY,
      1      LCBOT,LCTOP,LCSC2,LCTRPY,IUNIT(1),ISS,
      2      NCOL,NROW,NLAY,IOUT,IBCFCB)
       IF(IUNIT(2).GT.0) CALL WEL1AL(ISUM,LENX,LCWELL,MXWELL,NWELLS,
      1            IUNIT(2),IOUT,IWELCB)
       IF(IUNIT(3).GT.0) CALL DRN1AL(ISUM,LENX,LCDRAI,NDRAIN,MXDRN,
      1            IUNIT(3),IOUT,IDRNCB)
       IF(IUNIT(8).GT.0) CALL RCH1AL(ISUM,LENX,LCIRCH,LCRECH,NRCHOP,
      1          NCOL,NROW,IUNIT(8),IOUT,IRCHCB)
       IF(IUNIT(5).GT.0) CALL EVT1AL(ISUM,LENX,LCIEVT,LCEVTR,LCEXDP,
      1          LCSURF,NCOL,NROW,NEVTOP,IUNIT(5),IOUT,IEVTCB)
       IF(IUNIT(4).GT.0) CALL RIV1AL(ISUM,LENX,LCRIVR,MXRIVR,NRIVER,
      1            IUNIT(4),IOUT,IRIVCB)
C------STREAMFLOW-ROUTING PACKAGE..MODULE STR1AL
       IF(IUNIT(13).GT.0) CALL STR1AL(ISUM,LENX,LCSTRM,ICSTRM,MXSTRM,     STR1
      1                 NSTREM,IUNIT(13),IOUT,ISTCB1,ISTCB2,NSS,NTRIB,     STR1
      2                 NDIV,ICALC,CONST,LCTBAR,LCTRIB,LCIVAR)             STR1
C------END OF MODULE STR1AL CALL STATEMENT
```

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```
      IF(IUNIT(7).GT.0) CALL GHB1AL(ISUM,LENX,LCBNDS,NBOUND,MXBND,
     1          IUNIT(7),IOUT,IGHBCB)
      IF(IUNIT(9).GT.0) CALL SIP1AL(ISUM,LENX,LCEL,LCFL,LCGL,LCV,
     1          LCHDCG,LCLRCH,LCW,MXITER,NPARM,NCOL,NROW,NLAY,
     2          IUNIT(9),IOUT)
      IF(IUNIT(11).GT.0) CALL SOR1AL(ISUM,LENX,LCA,LCRES,LCHDCG,LCLRCH,
     1          LCIEQP,MXITER,NCOL,NLAY,NSLICE,MBW,IUNIT(11),IOUT)
C
C5------IF THE "X" ARRAY IS NOT BIG ENOUGH THEN STOP.
      IF(ISUM-1.GT.LENX) STOP
C
C6------READ AND PREPARE INFORMATION FOR ENTIRE SIMULATION.
      CALL BAS1RP(X(LCIBOU),X(LCHNEW),X(LCSTRT),X(LCHOLD),
     1          ISTRT,INBAS,HEADNG,NCOL,NROW,NLAY,NODES,VBVL,X(LCIOFL),
     2          IUNIT(12),IHEDFM,IDDNFM,IHEDUN,IDDNUN,IOUT)
      IF(IUNIT(1).GT.0) CALL BCF1RP(X(LCIBOU),X(LCHNEW),X(LCSC1),
     1          X(LCHY),X(LCCR),X(LCCC),X(LCCV),X(LCDELR),
     2          X(LCDELC),X(LCBOT),X(LCTOP),X(LCSC2),X(LCTRPY),
     3          IUNIT(1),ISS,NCOL,NROW,NLAY,NODES,IOUT)
      IF(IUNIT(9).GT.0) CALL SIP1RP(NPARM,MXITER,ACCL,HCLOSE,X(LCW),
     1          IUNIT(9),IPCALC,IPRSIP,IOUT)
      IF(IUNIT(11).GT.0) CALL SOR1RP(MXITER,ACCL,HCLOSE,IUNIT(11),
     1          IPRSOR,IOUT)
C
C7------SIMULATE EACH STRESS PERIOD.
      DO 300 KPER=1,NPER
      KKPER=KPER
C
C7A-----READ STRESS PERIOD TIMING INFORMATION.
      CALL BAS1ST(NSTP,DELT,TSMULT,PERTIM,KKPER,INBAS,IOUT)
C
C7B-----READ AND PREPARE INFORMATION FOR STRESS PERIOD.
      IF(IUNIT(2).GT.0) CALL WEL1RP(X(LCWELL),NWELLS,MXWELL,IUNIT(2),
     1          IOUT)
      IF(IUNIT(3).GT.0) CALL DRN1RP(X(LCDRAI),NDRAIN,MXDRN,IUNIT(3),
     1            IOUT)
      IF(IUNIT(8).GT.0) CALL RCH1RP(NRCHOP,X(LCIRCH),X(LCRECH),
     1          X(LCDELR),X(LCDELC),NROW,NCOL,IUNIT(8),IOUT)
      IF(IUNIT(5).GT.0) CALL EVT1RP(NEVTOP,X(LCIEVT),X(LCEVTR),
     1          X(LCEXDP),X(LCSURF),X(LCDELR),X(LCDELC),NCOL,NROW,
     1          IUNIT(5),IOUT)
      IF(IUNIT(4).GT.0) CALL RIV1RP(X(LCRIVR),NRIVER,MXRIVR,IUNIT(4),
     1            IOUT)
C------STREAMFLOW-ROUTING PACKAGE MODULE STR1RP
      IF(IUNIT(13).GT.0) CALL STR1RP(X(LCSTRM),X(ICSTRM),NSTREM,       STR1
     1              MXSTRM,IUNIT(13),IOUT,X(LCTBAR),NDIV,NSS,          STR1
     1              NTRIB,X(LCIVAR),ICALC,IPTFLG)                      STR1
C------END OF MODULE STR1RP CALL STATEMENT
      IF(IUNIT(7).GT.0) CALL GHB1RP(X(LCBNDS),NBOUND,MXBND,IUNIT(7),
     1            IOUT)
C
C7C-----SIMULATE EACH TIME STEP.
      DO 200 KSTP=1,NSTP
      KKSTP=KSTP
```

```
C
C7C1----CALCULATE TIME STEP LENGTH. SET HOLD=HNEW..
      CALL BAS1AD(DELT,TSMULT,TOTIM,PERTIM,X(LCHNEW),X(LCHOLD),KKSTP,
     1                 NCOL,NROW,NLAY)
C
C7C2----ITERATIVELY FORMULATE AND SOLVE THE EQUATIONS.
      DO 100 KITER=1,MXITER
      KKITER=KITER
C
C7C2A---FORMULATE THE FINITE DIFFERENCE EQUATIONS.
      CALL BAS1FM(X(LCHCOF),X(LCRHS),NODES)
      IF(IUNIT(1).GT.0) CALL BCF1FM(X(LCHCOF),X(LCRHS),X(LCHOLD),
     1        X(LCSC1),X(LCHNEW),X(LCIBOU),X(LCCR),X(LCCC),X(LCCV),
     2        X(LCHY),X(LCTRPY),X(LCBOT),X(LCTOP),X(LCSC2),
     3        X(LCDELR),X(LCDELC),DELT,ISS,KKITER,KKSTP,KKPER,NCOL,
     4        NROW,NLAY,IOUT)
      IF(IUNIT(2).GT.0) CALL WEL1FM(NWELLS,MXWELL,X(LCRHS),X(LCWELL),
     1        X(LCIBOU),NCOL,NROW,NLAY)
      IF(IUNIT(3).GT.0) CALL DRN1FM(NDRAIN,MXDRN,X(LCDRAI),X(LCHNEW),
     1        X(LCHCOF),X(LCRHS),X(LCIBOU),NCOL,NROW,NLAY)
      IF(IUNIT(8).GT.0) CALL RCH1FM(NRCHOP,X(LCIRCH),X(LCRECH),
     1        X(LCRHS),X(LCIBOU),NCOL,NROW,NLAY)
      IF(IUNIT(5).GT.0) CALL EVT1FM(NEVTOP,X(LCIEVT),X(LCEVTR),
     1        X(LCEXDP),X(LCSURF),X(LCRHS),X(LCHCOF),X(LCIBOU),
     1        X(LCHNEW),NCOL,NROW,NLAY)
      IF(IUNIT(4).GT.0) CALL RIV1FM(NRIVER,MXRIVR,X(LCRIVR),X(LCHNEW),
     1        X(LCHCOF),X(LCRHS),X(LCIBOU),NCOL,NROW,NLAY)
C-------STREAMFLOW-ROUTING PACKAGE MODULE STR1FM
      IF(IUNIT(13).GT.0) CALL STR1FM(NSTREM,X(LCSTRM),X(ICSTRM),        STR1
     1                         X(LCHNEW),X(LCHCOF),X(LCRHS),            STR1
     2              X(LCIBOU),MXSTRM,NCOL,NROW,NLAY,IOUT,NSS,           STR1
     3              X(LCTBAR),NTRIB,X(LCTRIB),X(LCIVAR),ICALC,CONST)    STR1
C------END OF MODULE STR1FM CALL STATEMENT
      IF(IUNIT(7).GT.0) CALL GHB1FM(NBOUND,MXBND,X(LCBNDS),X(LCHCOF),
     1        X(LCRHS),X(LCIBOU),NCOL,NROW,NLAY)
C
C7C2B---MAKE ONE CUT AT AN APPROXIMATE SOLUTION.
      IF(IUNIT(9).GT.0) CALL SIP1AP(X(LCHNEW),X(LCIBOU),X(LCCR),X(LCCC),
     1        X(LCCV),X(LCHCOF),X(LCRHS),X(LCEL),X(LCFL),X(LCGL),X(LCV),
     2        X(LCW),X(LCHDCG),X(LCLRCH),NPARM,KKITER,HCLOSE,ACCL,ICNVG,
     3        KKSTP,KKPER,IPCALC,IPRSIP,MXITER,NSTP,NCOL,NROW,NLAY,NODES,
     4        IOUT)
      IF(IUNIT(11).GT.0) CALL SOR1AP(X(LCHNEW),X(LCIBOU),X(LCCR),
     1        X(LCCC),X(LCCV),X(LCHCOF),X(LCRHS),X(LCA),X(LCRES),X(LCIEQP),
     2        X(LCHDCG),X(LCLRCH),KKITER,HCLOSE,ACCL,ICNVG,KKSTP,KKPER,
     3        IPRSOR,MXITER,NSTP,NCOL,NROW,NLAY,NSLICE,MBW,IOUT)
C
C7C2C---IF CONVERGENCE CRITERION HAS BEEN MET STOP ITERATING.
      IF(ICNVG.EQ.1) GO TO 110
  100 CONTINUE
      KITER=MXITER
  110 CONTINUE
C
C7C3----DETERMINE WHICH OUTPUT IS NEEDED.
```

```
      CALL BAS1OC(NSTP,KKSTP,ICNVG,X(LCIOFL),NLAY,
     1 IBUDFL,ICBCFL,IHDDFL,IUNIT(12),IOUT)
C
C7C4----CALCULATE BUDGET TERMS. SAVE CELL-BY-CELL FLOW TERMS.
      MSUM=1
      IF(IUNIT(1).GT.0) CALL BCF1BD(VBNM,VBVL,MSUM,X(LCHNEW),
     1     X(LCIBOU),X(LCHOLD),X(LCSC1),X(LCCR),X(LCCC),X(LCCV),
     2     X(LCTOP),X(LCSC2),DELT,ISS,NCOL,NROW,NLAY,KKSTP,KKPER,
     3     IBCFCB,ICBCFL,X(LCBUFF),IOUT)
      IF(IUNIT(2).GT.0) CALL WEL1BD(NWELLS,MXWELL,VBNM,VBVL,MSUM,
     1     X(LCWELL),X(LCIBOU),DELT,NCOL,NROW,NLAY,KKSTP,KKPER,IWELCB,
     1     ICBCFL,X(LCBUFF),IOUT)
      IF(IUNIT(3).GT.0) CALL DRN1BD(NDRAIN,MXDRN,VBNM,VBVL,MSUM,
     1     X(LCDRAI),DELT,X(LCHNEW),NCOL,NROW,NLAY,X(LCIBOU),KKSTP,
     2     KKPER,IDRNCB,ICBCFL,X(LCBUFF),IOUT)
      IF(IUNIT(8).GT.0) CALL RCH1BD(NRCHOP,X(LCIRCH),X(LCRECH),
     1     X(LCIBOU),NROW,NCOL,NLAY,DELT,VBVL,VBNM,MSUM,KKSTP,KKPER,
     2     IRCHCB,ICBCFL,X(LCBUFF),IOUT)
      IF(IUNIT(5).GT.0) CALL EVT1BD(NEVTOP,X(LCIEVT),X(LCEVTR),
     1     X(LCEXDP),X(LCSURF),X(LCIBOU),X(LCHNEW),NCOL,NROW,NLAY,
     2     DELT,VBVL,VBNM,MSUM,KKSTP,KKPER,IEVTCB,ICBCFL,X(LCBUFF),IOUT)
      IF(IUNIT(4).GT.0) CALL RIV1BD(NRIVER,MXRIVR,X(LCRIVR),X(LCIBOU),
     1     X(LCHNEW),NCOL,NROW,NLAY,DELT,VBVL,VBNM,MSUM,
     2     KKSTP,KKPER,IRIVCB,ICBCFL,X(LCBUFF),IOUT)
C------STREAMFLOW-ROUTING PACKAGE MODULE STR1BD
      IF(IUNIT(13).GT.0) CALL STR1BD(NSTREM,X(LCSTRM),X(ICSTRM),     STR1
     1     X(LCIBOU),MXSTRM,X(LCHNEW),NCOL,NROW,NLAY,DELT,VBVL,       STR1
     2     VBNM,MSUM,KKSTP,KKPER,ISTCB1,ISTCB2,ICBCFL,X(LCBUFF),IOUT, STR1
     3     NTRIB,NSS,X(LCTRIB),X(LCTBAR),X(LCIVAR),ICALC,CONST,IPTFLG) STR1
C------END OF MODULE STR1BD CALL STATEMENT
      IF(IUNIT(7).GT.0) CALL GHB1BD(NBOUND,MXBND,VBNM,VBVL,MSUM,
     1     X(LCBNDS),DELT,X(LCHNEW),NCOL,NROW,NLAY,X(LCIBOU),KKSTP,
     2     KKPER,IGHBCB,ICBCFL,X(LCBUFF),IOUT)
C
C7C5---PRINT AND OR SAVE HEADS AND DRAWDOWNS. PRINT OVERALL BUDGET.
      CALL BAS1OT(X(LCHNEW),X(LCSTRT),ISTRT,X(LCBUFF),X(LCIOFL),
     1       MSUM,X(LCIBOU),VBNM,VBVL,KKSTP,KKPER,DELT,
     2       PERTIM,TOTIM,ITMUNI,NCOL,NROW,NLAY,ICNVG,
     3       IHDDFL,IBUDFL,IHEDFM,IHEDUN,IDDNFM,IDDNUN,IOUT)
C
C7C6----IF ITERATION FAILED TO CONVERGE THEN STOP.
      IF(ICNVG.EQ.0) STOP
  200 CONTINUE
  300 CONTINUE
C
C8------END PROGRAM
      STOP
C
      END
```

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INPUT DATA SETS AND PRINTED RESULTS FOR TEST PROBLEM 1

This problem tests the ability of the Streamflow-Routing Package to accumulate leakage from an aquifer into a stream with a constant stage. Details of the test problem and results are discussed in the section "Results of Test Simulations."

Listing of Input Data Sets for Test Problem 1

Listing of Input Data for Basic Package

Input for the Basic Package follows the column numbers. The input consists of 152 records (lines). Input for package is read from the FORTRAN unit number specified in the MAIN program.

Column Numbers

```
         1         2         3         4         5         6         7         8
12345678901234567890123456789012345678901234567890123456789012345678901234567890
TEST PROBLEM1--CONSTANT STREAM STAGE AND VARIABLE RECHARGE TO AQUIFER:

         1        13        39       144         1
    7                11 13        14 15
         0         1
         0         1
     999.
         0      55.0
 1296000.         2         1.5
Previous line is repeated 143 times.
```

Listing of Input Data for Strongly-Implicit Procedure Package

Input for the Strongly-Implicit Procedure Package follows the column numbers. The input consists of 2 records (lines). Input for package is read from FORTRAN unit 13 as specified in the data set for the Basic Package.

Column Numbers

```
         1         2         3         4         5         6         7         8
12345678901234567890123456789012345678901234567890123456789012345678901234567890
       150         5
       1.    0.0001         1         0         0
```

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Listing of Input Data for Block-Centered Flow Package

Input for the Block-Centered Flow Package follows the column numbers. The input data consists of 11 records (lines). Input for package is read from FORTRAN unit number 7 as specified in the data set for the Basic Package.

Column Numbers

```
        1         2         3         4         5         6         7         8
12345678901234567890123456789012345678901234567890123456789012345678901234567890
          0         0
0
          0         1.
          7       100. (15F5.0)
     3.   2.   2.   2.   2.   2.   2.   2.   2.   2.   2.   2.   2.   2.   2.
     2.   2.   2.   2.   2.   2.   2.   2.   2.   2.   2.   2.   2.   2.   2.
     2.   2.   2.   2.   2.   2.   2.   2.   3.
          0      1000.
          0       0.20
          0   0.037000
          0        0.
```

Listing of Input Data For Output Control Package

Input for the Output Control Package follows the column numbers. The input data consists of 338 records (lines). Input for package is read from FORTRAN unit number 14 as specified in the data set for the Basic Package.

Column Numbers

```
        1         2         3         4         5         6         7         8
12345678901234567890123456789012345678901234567890123456789012345678901234567890
          5         5         0         0
          0         0         0         0
          0         0         0         0
         -1         0         0         0
previous line repeated 238 times
          0         0         0         0
          0         0         0         0
          0         1         1         1
          1         0         0         0
sequence of previous 4 lines repeated 23 times
```

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Listing of Input Data for Streamflow-Routing Package

Input for the Streamflow-Routing Package follows the column numbers. The input consists of 158 records (lines). Input for package is read from FORTRAN unit number 15 as specified in the data set for the Basic Package.

Column Numbers

```
         1         2         3         4         5         6         7         8
1234567890123456789012345678901234567890123456789012345678901234567890123456789 0
          13        1         0         0         0         0        -1         0
          13        0         0
1    1   20   1    1              0.01    50.0     37.037       0.0       0.0
1    2   20   1    2                      50.0     37.037       0.0       0.0
1    3   20   1    3                      50.0     37.037       0.0       0.0
1    4   20   1    4                      50.0     37.037       0.0       0.0
1    5   20   1    5                      50.0     37.037       0.0       0.0
1    6   20   1    6                      50.0     37.037       0.0       0.0
1    7   20   1    7                      50.0     37.037       0.0       0.0
1    8   20   1    8                      50.0     37.037       0.0       0.0
1    9   20   1    9                      50.0     37.037       0.0       0.0
1   10   20   1   10                      50.0     37.037       0.0       0.0
1   11   20   1   11                      50.0     37.037       0.0       0.0
1   12   20   1   12                      50.0     37.037       0.0       0.0
1   13   20   1   13                      50.0     37.037       0.0       0.0
         -1        0         0
previous line repeated 142 times
```

Listing of Input Data for Recharge Package

Input for the Recharge Package follows the column numbers. The input consists of 289 records (lines). Input for package is read from FORTRAN unit number 11 as specified in the data set for the Basic Package.

Column Numbers

```
         1         2         3         4         5         6         7         8
1234567890123456789012345678901234567890123456789012345678901234567890123456789 0
          1         0
          1
          02.8935E-09
          1
          02.7778E-08
          1
          07.1181E-08
          1
          01.2095E-07
          1
          01.6435E-07
```

Column Numbers

```
       1         2         3         4         5         6         7         8
1234567890123456789012345678901234567890123456789012345678901234567890123456789
    1
    01.8924E-07
    1
    01.8924E-07
    1
    01.6435E-07
    1
    01.2095E-07
    1
    07.1181E-08
    1
    02.7778E-08
    1
    02.8935E-09
    1
    0        0.0
    1
    0        0.00
    1
    0        0.00
    1
    0        0.00
    1
    0        0.00
    1
    0        0.00
    1
    0        0.0
    1
    0        0.00
    1
    0        0.00
    1
    0        0.00
    1
    0        0.00
    1
    0        0.00
sequence of previous 48 lines repeated 5 times
```

U.S. GEOLOGICAL SURVEY MODULAR FINITE-DIFFERENCE GROUND-WATER MODEL

TEST PROBLEM 1--CONSTANT STREAM STAGE AND VARIABLE RECHARGE TO AQUIFER:

    1 LAYERS   13 ROWS   39 COLUMNS
144 STRESS PERIOD(S) IN SIMULATION
MODEL TIME UNIT IS SECONDS

I/O UNITS:
ELEMENT OF IUNIT: 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
         I/O UNIT: 7 0 0 0 0 0 0 11 13 0 0 14 15 0 0 0 0 0 0 0 0 0 0 0

BAS1 -- BASIC MODEL PACKAGE, VERSION 1, 9/1/87 INPUT READ FROM UNIT 5
ARRAYS RHS AND BUFF WILL SHARE MEMORY.
START HEAD WILL BE SAVED
     4619 ELEMENTS IN X ARRAY ARE USED BY BAS
     4619 ELEMENTS OF X ARRAY USED OUT OF 200000

BCF1 -- BLOCK-CENTERED FLOW PACKAGE, VERSION 1, 9/1/87 INPUT READ FROM UNIT 7
TRANSIENT SIMULATION
      LAYER AQUIFER TYPE
      ----
        1   0
      508 ELEMENTS IN X ARRAY ARE USED BY BCF
     5127 ELEMENTS OF X ARRAY USED OUT OF 200000

RCH1 -- RECHARGE PACKAGE, VERSION 1, 9/1/87 INPUT READ FROM UNIT 11
OPTION 1 -- RECHARGE TO TOP LAYER
      507 ELEMENTS OF X ARRAY USED FOR RECHARGE
     5634 ELEMENTS OF X ARRAY USED OUT OF 200000

STRM -- STREAM PACKAGE, VERSION 1, 10/23/87 INPUT READ FROM UNIT 15
MAXIMUM OF   13 STREAM NODES

NUMBER OF STREAM SEGMENTS IS   1

NUMBER OF STREAM TRIBUTARIES IS   0

      210 ELEMENTS IN X ARRAY ARE USED FOR STREAMS
     5844 ELEMENTS OF X ARRAY USED OUT OF 200000

SIP1 -- STRONGLY IMPLICIT PROCEDURE SOLUTION PACKAGE, VERSION 1, 9/1/87 INPUT READ FROM UNIT 13
MAXIMUM OF 150 ITERATIONS ALLOWED FOR CLOSURE
 5 ITERATION PARAMETERS
     2633 ELEMENTS IN X ARRAY ARE USED BY SIP
     8477 ELEMENTS OF X ARRAY USED OUT OF 200000

STRESS PERIOD NO. 121, LENGTH =   1296000.

NUMBER OF TIME STEPS =   2

MULTIPLIER FOR DELT =   1.500

INITIAL TIME STEP SIZE =   518400.0

RECHARGE = 0.2893500E-08

REUSING STREAM NODES FROM LAST STRESS PERIOD

   4 ITERATIONS FOR TIME STEP   1 IN STRESS PERIOD121

HEAD/DRAWDOWN PRINTOUT FLAG = 0   TOTAL BUDGET PRINTOUT FLAG = 0   CELL-BY-CELL FLOW TERM FLAG = 0
OUTPUT FLAGS FOR ALL LAYERS ARE THE SAME:
   HEAD   DRAWDOWN HEAD   DRAWDOWN
 PRINTOUT PRINTOUT SAVE   SAVE
----
    0   0   0   0

   4 ITERATIONS FOR TIME STEP   2 IN STRESS PERIOD121
MAXIMUM HEAD CHANGE FOR EACH ITERATION:

  HEAD CHANGE LAYER,ROW,COL HEAD CHANGE LAYER,ROW,COL HEAD CHANGE LAYER,ROW,COL HEAD CHANGE LAYER,ROW,COL HEAD CHANGE LAYER,ROW,COL

  -0.1584   (1, 13, 39) -0.2075E-01 (1, 2, 2) -0.1028E-02 (1, 6, 4) -0.1414E-04 (1, 13, 1)

HEAD/DRAWDOWN PRINTOUT FLAG = 1   TOTAL BUDGET PRINTOUT FLAG = 1   CELL-BY-CELL FLOW TERM FLAG = 1
OUTPUT FLAGS FOR ALL LAYERS ARE THE SAME:
   HEAD   DRAWDOWN HEAD   DRAWDOWN
 PRINTOUT PRINTOUT SAVE   SAVE
----
    1   0   0   0

LAYER	ROW	COLUMN	STREAM NUMBER	REACH NUMBER	FLOW INTO STREAM REACH	FLOW INTO AQUIFER	FLOW OUT OF STREAM REACH
1	1	20	1	1	0.100E-01	-.237	0.247
1	2	20	1	2	0.247	-.237	0.484
1	3	20	1	3	0.484	-.237	0.721
1	4	20	1	4	0.721	-.237	0.958
1	5	20	1	5	0.958	-.237	1.20
1	6	20	1	6	1.20	-.237	1.43
1	7	20	1	7	1.43	-.237	1.67
1	8	20	1	8	1.67	-.237	1.91
1	9	20	1	9	1.91	-.237	2.14
1	10	20	1	10	2.14	-.237	2.38
1	11	20	1	11	2.38	-.237	2.62
1	12	20	1	12	2.62	-.237	2.85
1	13	20	1	13	2.85	-.237	3.09

HEAD IN LAYER 1 AT END OF TIME STEP 2 IN STRESS PERIOD121

```
       1       2       3       4       5       6       7       8       9      10      11      12      13      14      15
      16      17      18      19      20      21      22      23      24      25      26      27      28      29      30
      31      32      33      34      35      36      37      38      39
......................................................................................................................

 1  58.049  57.957  57.836  57.666  57.450  57.188  56.882  56.534  56.145  55.719  55.257  54.762  54.237  53.686  53.111
    52.516  51.905  51.281  50.647  50.006  50.647  51.281  51.905  52.516  53.111  53.686  54.237  54.762  55.257  55.719
    56.145  56.534  56.882  57.188  57.450  57.666  57.836  57.957  58.049

 2  58.049  57.957  57.836  57.666  57.450  57.188  56.882  56.534  56.145  55.719  55.257  54.762  54.237  53.686  53.111
    52.516  51.905  51.281  50.647  50.006  50.647  51.281  51.905  52.516  53.111  53.686  54.237  54.762  55.257  55.719
    56.145  56.534  56.882  57.188  57.450  57.666  57.836  57.957  58.049

 3  58.049  57.957  57.836  57.666  57.450  57.188  56.882  56.534  56.145  55.719  55.257  54.762  54.237  53.686  53.111
    52.516  51.905  51.281  50.647  50.006  50.647  51.281  51.905  52.516  53.111  53.686  54.237  54.762  55.257  55.719
    56.145  56.534  56.882  57.188  57.450  57.666  57.836  57.957  58.049

 4  58.049  57.957  57.836  57.666  57.450  57.188  56.882  56.534  56.145  55.719  55.257  54.762  54.237  53.686  53.111
    52.516  51.905  51.281  50.647  50.006  50.647  51.281  51.905  52.516  53.111  53.686  54.237  54.762  55.257  55.719
    56.145  56.534  56.882  57.188  57.450  57.666  57.836  57.957  58.049

 5  58.049  57.957  57.836  57.666  57.450  57.188  56.882  56.534  56.145  55.719  55.257  54.762  54.237  53.686  53.111
    52.516  51.905  51.281  50.647  50.006  50.647  51.281  51.905  52.516  53.111  53.686  54.237  54.762  55.257  55.719
    56.145  56.534  56.882  57.188  57.450  57.666  57.836  57.957  58.049

 6  58.049  57.957  57.836  57.666  57.450  57.188  56.882  56.534  56.145  55.719  55.257  54.762  54.237  53.686  53.111
    52.516  51.905  51.281  50.647  50.006  50.647  51.281  51.905  52.516  53.111  53.686  54.237  54.762  55.257  55.719
    56.145  56.534  56.882  57.188  57.450  57.666  57.836  57.957  58.049

 7  58.049  57.957  57.836  57.666  57.450  57.188  56.882  56.534  56.145  55.719  55.257  54.762  54.237  53.686  53.111
    52.516  51.905  51.281  50.647  50.006  50.647  51.281  51.905  52.516  53.111  53.686  54.237  54.762  55.257  55.719
    56.145  56.534  56.882  57.188  57.450  57.666  57.836  57.957  58.049

 8  58.049  57.957  57.836  57.666  57.450  57.188  56.882  56.534  56.145  55.719  55.257  54.762  54.237  53.686  53.111
    52.516  51.905  51.281  50.647  50.006  50.647  51.281  51.905  52.516  53.111  53.686  54.237  54.762  55.257  55.719
    56.145  56.534  56.882  57.188  57.450  57.666  57.836  57.957  58.049

 9  58.049  57.957  57.836  57.666  57.450  57.188  56.882  56.534  56.145  55.719  55.257  54.762  54.237  53.686  53.111
    52.516  51.905  51.281  50.647  50.006  50.647  51.281  51.905  52.516  53.111  53.686  54.237  54.762  55.257  55.719
    56.145  56.534  56.882  57.188  57.450  57.666  57.836  57.957  58.049

10  58.049  57.957  57.836  57.666  57.450  57.188  56.882  56.534  56.145  55.719  55.257  54.762  54.237  53.686  53.111
    52.516  51.905  51.281  50.647  50.006  50.647  51.281  51.905  52.516  53.111  53.686  54.237  54.762  55.257  55.719
    56.145  56.534  56.882  57.188  57.450  57.666  57.836  57.957  58.049

11  58.049  57.957  57.836  57.666  57.450  57.188  56.882  56.534  56.145  55.719  55.257  54.762  54.237  53.686  53.111
    52.516  51.905  51.281  50.647  50.006  50.647  51.281  51.905  52.516  53.111  53.686  54.237  54.762  55.257  55.719
    56.145  56.534  56.882  57.188  57.450  57.666  57.836  57.957  58.049

12  58.049  57.957  57.836  57.666  57.450  57.188  56.882  56.534  56.145  55.719  55.257  54.762  54.237  53.686  53.111
    52.516  51.905  51.281  50.647  50.006  50.647  51.281  51.905  52.516  53.111  53.686  54.237  54.762  55.257  55.719
    56.145  56.534  56.882  57.188  57.450  57.666  57.836  57.957  58.049

13  58.049  57.957  57.836  57.666  57.450  57.188  56.882  56.534  56.145  55.719  55.257  54.762  54.237  53.686  53.111
    52.516  51.905  51.281  50.647  50.006  50.647  51.281  51.905  52.516  53.111  53.686  54.237  54.762  55.257  55.719
    56.145  56.534  56.882  57.188  57.450  57.666  57.836  57.957  58.049
```

VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP 2 IN STRESS PERIOD121

```
     CUMULATIVE VOLUMES     L**3                    RATES FOR THIS TIME STEP     L**3/T
     ------------------                             ------------------------


            IN:                                              IN:
            ---                                              ---
         STORAGE =   0.41038E+09                          STORAGE =    2.7859
   CONSTANT HEAD =   0.00000                         CONSTANT HEAD =    0.00000
        RECHARGE =   0.77725E+09                         RECHARGE =    0.30091
   STREAM LEAKAGE =  0.00000                        STREAM LEAKAGE =   0.00000


        TOTAL IN =   0.11876E+10                         TOTAL IN =    3.0868

            OUT:                                             OUT:
            ----                                             ----
         STORAGE =   0.41335E+09                          STORAGE =    0.00000
   CONSTANT HEAD =   0.00000                         CONSTANT HEAD =    0.00000
        RECHARGE =   0.00000                              RECHARGE =    0.00000
   STREAM LEAKAGE =  0.77386E+09                       STREAM LEAKAGE =   3.0820


       TOTAL OUT =   0.11872E+10                        TOTAL OUT =    3.0820


       IN - OUT =   0.42240E+06                         IN - OUT =    0.48499E-02

   PERCENT DISCREPANCY =          0.04            PERCENT DISCREPANCY =           0.16
```


TIME SUMMARY AT END OF TIME STEP 2 IN STRESS PERIOD121

```
                           SECONDS      MINUTES      HOURS       DAYS        YEARS
                           -------------------------------------------------------------
        TIME STEP LENGTH     777600.     12960.0      216.000     9.00000     0.246407E-01
       STRESS PERIOD TIME    0.129600E+07  21600.0    360.000    15.0000      0.410678E-01
   TOTAL SIMULATION TIME     0.156816E+09  0.261360E+07  43560.0  1815.00     4.96920
```

STRESS PERIOD NO. 134, LENGTH = 1296000.

NUMBER OF TIME STEPS =   2

MULTIPLIER FOR DELT =   1.500

INITIAL TIME STEP SIZE =   518400.0

RECHARGE = 0.0000000

REUSING STREAM NODES FROM LAST STRESS PERIOD

    4 ITERATIONS FOR TIME STEP   1 IN STRESS PERIOD134

HEAD/DRAWDOWN PRINTOUT FLAG = 0   TOTAL BUDGET PRINTOUT FLAG = 0   CELL-BY-CELL FLOW TERM FLAG = 0
OUTPUT FLAGS FOR ALL LAYERS ARE THE SAME:
   HEAD   DRAWDOWN HEAD DRAWDOWN
PRINTOUT PRINTOUT SAVE   SAVE
----
    0   0   0   0

    4 ITERATIONS FOR TIME STEP   2 IN STRESS PERIOD134

MAXIMUM HEAD CHANGE FOR EACH ITERATION:
  HEAD CHANGE LAYER,ROW,COL HEAD CHANGE LAYER,ROW,COL HEAD CHANGE LAYER,ROW,COL HEAD CHANGE LAYER,ROW,COL HEAD CHANGE LAYER,ROW,COL

  -0.2121   (1, 13, 9) -0.2933E-01 (1, 2, 8) -0.1548E-02 (1, 7, 7) -0.2070E-04 (1, 13, 1)

HEAD/DRAWDOWN PRINTOUT FLAG = 1   TOTAL BUDGET PRINTOUT FLAG = 1   CELL-BY-CELL FLOW TERM FLAG = 1
OUTPUT FLAGS FOR ALL LAYERS ARE THE SAME:
   HEAD   DRAWDOWN HEAD DRAWDOWN
PRINTOUT PRINTOUT SAVE   SAVE
----
    1   0   0   0

LAYER	ROW	COLUMN	STREAM NUMBER	REACH NUMBER	FLOW INTO STREAM REACH	FLOW INTO AQUIFER	FLOW OUT OF STREAM REACH
1	1	20	1	1	0.100E-01	-.379	0.389
1	2	20	1	2	0.389	-.379	0.767
1	3	20	1	3	0.767	-.379	1.15
1	4	20	1	4	1.15	-.379	1.52
1	5	20	1	5	1.52	-.379	1.90
1	6	20	1	6	1.90	-.379	2.28
1	7	20	1	7	2.28	-.379	2.66
1	8	20	1	8	2.66	-.379	3.04
1	9	20	1	9	3.04	-.379	3.42
1	10	20	1	10	3.42	-.379	3.80
1	11	20	1	11	3.80	-.379	4.18
1	12	20	1	12	4.18	-.379	4.55
1	13	20	1	13	4.55	-.379	4.93

```
                    HEAD IN LAYER  1 AT END OF TIME STEP  2 IN STRESS PERIOD134
         ------------------------------------------------------------------
           1       2       3       4       5       6       7       8       9      10      11      12      13      14      15
          16      17      18      19      20      21      22      23      24      25      26      27      28      29      30
          31      32      33      34      35      36      37      38      39
         .............................................................................................................................

  1    61.742  61.632  61.485  61.279  61.011  60.682  60.291  59.837  59.320  58.739  58.094  57.387  56.621  55.798  54.922
       54.000  53.039  52.047  51.034  50.010  51.034  52.047  53.039  54.000  54.922  55.798  56.621  57.387  58.094  58.739
       59.320  59.837  60.291  60.682  61.011  61.278  61.485  61.632  61.742

  2    61.742  61.632  61.485  61.279  61.011  60.682  60.291  59.837  59.320  58.739  58.094  57.387  56.621  55.798  54.922
       54.000  53.039  52.047  51.034  50.010  51.034  52.047  53.039  54.000  54.922  55.798  56.621  57.387  58.094  58.739
       59.320  59.837  60.291  60.682  61.011  61.278  61.485  61.632  61.742

  3    61.742  61.632  61.485  61.279  61.011  60.682  60.291  59.837  59.320  58.739  58.094  57.387  56.621  55.798  54.922
       54.000  53.039  52.047  51.034  50.010  51.034  52.047  53.039  54.000  54.922  55.798  56.621  57.387  58.094  58.739
       59.320  59.837  60.291  60.682  61.011  61.278  61.485  61.632  61.742

  4    61.742  61.632  61.485  61.279  61.011  60.682  60.291  59.837  59.320  58.739  58.094  57.387  56.621  55.798  54.922
       54.000  53.039  52.047  51.034  50.010  51.034  52.047  53.039  54.000  54.922  55.798  56.621  57.387  58.094  58.739
       59.320  59.837  60.291  60.682  61.011  61.278  61.485  61.632  61.742

  5    61.742  61.632  61.485  61.279  61.011  60.682  60.291  59.837  59.320  58.739  58.094  57.387  56.621  55.798  54.922
       54.000  53.039  52.047  51.034  50.010  51.034  52.047  53.039  54.000  54.922  55.798  56.621  57.387  58.094  58.739
       59.320  59.837  60.291  60.682  61.011  61.278  61.485  61.632  61.742

  6    61.742  61.632  61.485  61.278  61.011  60.682  60.291  59.837  59.320  58.739  58.094  57.387  56.621  55.798  54.922
       54.000  53.039  52.047  51.034  50.010  51.034  52.047  53.039  54.000  54.922  55.798  56.621  57.387  58.094  58.739
       59.320  59.837  60.291  60.682  61.011  61.278  61.485  61.632  61.742

  7    61.742  61.632  61.485  61.278  61.011  60.682  60.291  59.837  59.320  58.739  58.094  57.387  56.621  55.798  54.922
       54.000  53.039  52.047  51.034  50.010  51.034  52.047  53.039  54.000  54.922  55.798  56.621  57.387  58.094  58.739
       59.320  59.837  60.291  60.682  61.011  61.278  61.485  61.632  61.742

  8    61.742  61.632  61.485  61.278  61.011  60.682  60.291  59.837  59.320  58.739  58.094  57.387  56.621  55.798  54.922
       54.000  53.039  52.047  51.034  50.010  51.034  52.047  53.039  54.000  54.922  55.798  56.621  57.387  58.094  58.739
       59.320  59.837  60.291  60.682  61.011  61.278  61.485  61.632  61.742

  9    61.742  61.632  61.485  61.278  61.011  60.682  60.291  59.837  59.320  58.739  58.094  57.387  56.621  55.798  54.922
       54.000  53.039  52.047  51.034  50.010  51.034  52.047  53.039  54.000  54.922  55.798  56.621  57.387  58.094  58.739
       59.320  59.837  60.291  60.682  61.011  61.279  61.485  61.632  61.742

 10    61.742  61.632  61.485  61.278  61.011  60.682  60.291  59.837  59.320  58.739  58.094  57.387  56.621  55.798  54.922
       54.000  53.039  52.047  51.034  50.010  51.034  52.047  53.039  54.000  54.922  55.798  56.621  57.387  58.094  58.739
       59.320  59.837  60.291  60.682  61.011  61.279  61.485  61.632  61.742

 11    61.742  61.632  61.485  61.278  61.011  60.682  60.291  59.837  59.320  58.739  58.094  57.387  56.621  55.798  54.922
       54.000  53.039  52.047  51.034  50.010  51.034  52.047  53.039  54.000  54.922  55.798  56.621  57.387  58.094  58.739
       59.320  59.837  60.291  60.682  61.011  61.279  61.485  61.632  61.742

 12    61.742  61.632  61.485  61.278  61.011  60.682  60.291  59.837  59.320  58.739  58.094  57.387  56.621  55.798  54.922
       54.000  53.039  52.047  51.034  50.010  51.034  52.047  53.039  54.000  54.922  55.798  56.621  57.387  58.094  58.739
       59.320  59.837  60.291  60.682  61.011  61.279  61.485  61.632  61.742

 13    61.742  61.632  61.485  61.278  61.011  60.682  60.291  59.837  59.320  58.739  58.094  57.387  56.621  55.798  54.922
       54.000  53.039  52.047  51.034  50.010  51.034  52.047  53.039  54.000  54.922  55.798  56.621  57.387  58.094  58.739
       59.320  59.837  60.291  60.682  61.011  61.279  61.485  61.632  61.742
```

VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP 2 IN STRESS PERIOD134

CUMULATIVE VOLUMES	L**3		RATES FOR THIS TIME STEP	L**3/T
-----------------			-----------------------	
IN:			IN:	
---			---	
STORAGE =	0.43765E+09		STORAGE =	4.9254
CONSTANT HEAD =	0.00000		CONSTANT HEAD =	0.00000
RECHARGE =	0.93224E+09		RECHARGE =	0.00000
STREAM LEAKAGE =	0.00000		STREAM LEAKAGE =	0.00000
TOTAL IN =	0.13699E+10		TOTAL IN =	4.9254
OUT:			OUT:	
----			----	
STORAGE =	0.49468E+09		STORAGE =	0.00000
CONSTANT HEAD =	0.00000		CONSTANT HEAD =	0.00000
RECHARGE =	0.00000		RECHARGE =	0.00000
STREAM LEAKAGE =	0.87473E+09		STREAM LEAKAGE =	4.9224
TOTAL OUT =	0.13694E+10		TOTAL OUT =	4.9224
IN - OUT =	0.47002E+06		IN - OUT =	0.30622E-02
PERCENT DISCREPANCY =	0.03		PERCENT DISCREPANCY =	0.06

TIME SUMMARY AT END OF TIME STEP 2 IN STRESS PERIOD134

	SECONDS	MINUTES	HOURS	DAYS	YEARS
	--				
TIME STEP LENGTH	777600.	12960.0	216.000	9.00000	0.246407E-01
STRESS PERIOD TIME	0.129600E+07	21600.0	360.000	15.0000	0.410678E-01
TOTAL SIMULATION TIME	0.173664E+09	0.289440E+07	48240.0	2010.00	5.50308

```
                        STRESS PERIOD NO. 140, LENGTH =   1296000.
                        ------------------------------------------------

                        NUMBER OF TIME STEPS =     2

                        MULTIPLIER FOR DELT =    1.500

                        INITIAL TIME STEP SIZE =  518400.0

                                        RECHARGE =  0.0000000

REUSING STREAM NODES FROM LAST STRESS PERIOD

     4 ITERATIONS FOR TIME STEP   1 IN STRESS PERIOD140

HEAD/DRAWDOWN PRINTOUT FLAG = 0     TOTAL BUDGET PRINTOUT FLAG = 0     CELL-BY-CELL FLOW TERM FLAG = 0
OUTPUT FLAGS FOR ALL LAYERS ARE THE SAME:
   HEAD    DRAWDOWN  HEAD  DRAWDOWN
PRINTOUT  PRINTOUT  SAVE   SAVE
----------------------------------
    0         0       0      0


     4 ITERATIONS FOR TIME STEP   2 IN STRESS PERIOD140

MAXIMUM HEAD CHANGE FOR EACH ITERATION:
  HEAD CHANGE LAYER,ROW,COL HEAD CHANGE LAYER,ROW,COL HEAD CHANGE LAYER,ROW,COL HEAD CHANGE LAYER,ROW,COL HEAD CHANGE LAYER,ROW,COL
-----------------------------------------------------------------------------------------------------------------------------------

  -0.1965     ( 1, 13, 39) -0.2610E-01 ( 1,  2,  3) -0.1310E-02 ( 1,  6,  4) -0.1804E-04 ( 1, 13,  1)


HEAD/DRAWDOWN PRINTOUT FLAG = 1     TOTAL BUDGET PRINTOUT FLAG = 1     CELL-BY-CELL FLOW TERM FLAG = 1
OUTPUT FLAGS FOR ALL LAYERS ARE THE SAME:
   HEAD    DRAWDOWN  HEAD  DRAWDOWN
PRINTOUT  PRINTOUT  SAVE   SAVE
----------------------------------
    1         0       0      0
```

LAYER	ROW	COLUMN	STREAM NUMBER	REACH NUMBER	FLOW INTO STREAM REACH	FLOW INTO AQUIFER	FLOW OUT OF STREAM REACH
1	1	20	1	1	0.100E-01	-.285	0.295
1	2	20	1	2	0.295	-.285	0.580
1	3	20	1	3	0.580	-.285	0.864
1	4	20	1	4	0.864	-.285	1.15
1	5	20	1	5	1.15	-.285	1.43
1	6	20	1	6	1.43	-.285	1.72
1	7	20	1	7	1.72	-.285	2.00
1	8	20	1	8	2.00	-.285	2.29
1	9	20	1	9	2.29	-.285	2.57
1	10	20	1	10	2.57	-.285	2.86
1	11	20	1	11	2.86	-.285	3.14
1	12	20	1	12	3.14	-.285	3.43
1	13	20	1	13	3.43	-.285	3.71

```
                    HEAD IN LAYER  1 AT END OF TIME STEP  2 IN STRESS PERIOD140
        ------------------------------------------------------------------------
            1       2       3       4       5       6       7       8       9      10      11      12      13      14      15
           16      17      18      19      20      21      22      23      24      25      26      27      28      29      30
           31      32      33      34      35      36      37      38      39
        ........................................................................................................................

  1     59.621  59.514  59.373  59.175  58.923  58.616  58.257  57.847  57.388  56.882  56.331  55.740  55.111  54.448  53.756
        53.037  52.299  51.544  50.778  50.008  50.778  51.544  52.299  53.037  53.756  54.448  55.111  55.740  56.331  56.882
        57.388  57.847  58.257  58.616  58.923  59.175  59.373  59.514  59.621

  2     59.621  59.514  59.373  59.175  58.923  58.616  58.257  57.847  57.388  56.882  56.331  55.740  55.111  54.448  53.756
        53.037  52.299  51.544  50.778  50.008  50.778  51.544  52.299  53.037  53.756  54.448  55.111  55.740  56.331  56.882
        57.388  57.847  58.257  58.616  58.923  59.175  59.373  59.514  59.621

  3     59.621  59.514  59.373  59.175  58.923  58.616  58.257  57.847  57.388  56.882  56.331  55.740  55.111  54.448  53.756
        53.037  52.299  51.544  50.778  50.008  50.778  51.544  52.299  53.037  53.756  54.448  55.111  55.740  56.331  56.882
        57.388  57.847  58.257  58.616  58.923  59.175  59.373  59.514  59.621

  4     59.621  59.514  59.373  59.175  58.923  58.616  58.257  57.847  57.388  56.882  56.331  55.740  55.111  54.448  53.756
        53.037  52.299  51.544  50.778  50.008  50.778  51.544  52.299  53.037  53.756  54.448  55.111  55.740  56.331  56.882
        57.388  57.847  58.257  58.616  58.923  59.175  59.373  59.514  59.621

  5     59.621  59.514  59.373  59.175  58.923  58.616  58.257  57.847  57.388  56.882  56.331  55.740  55.111  54.448  53.756
        53.037  52.299  51.544  50.778  50.008  50.778  51.544  52.299  53.037  53.756  54.448  55.111  55.740  56.331  56.882
        57.388  57.847  58.257  58.616  58.923  59.175  59.373  59.514  59.621

  6     59.621  59.514  59.373  59.175  58.923  58.616  58.257  57.847  57.388  56.882  56.331  55.740  55.111  54.448  53.756
        53.037  52.299  51.544  50.778  50.008  50.778  51.544  52.299  53.037  53.756  54.448  55.111  55.740  56.331  56.882
        57.388  57.847  58.257  58.616  58.923  59.175  59.373  59.514  59.621

  7     59.621  59.514  59.373  59.175  58.923  58.616  58.257  57.847  57.388  56.882  56.331  55.740  55.111  54.448  53.756
        53.037  52.299  51.544  50.778  50.008  50.778  51.544  52.299  53.037  53.756  54.448  55.111  55.740  56.331  56.882
        57.388  57.847  58.257  58.616  58.923  59.175  59.373  59.514  59.621

  8     59.621  59.514  59.373  59.175  58.923  58.616  58.257  57.847  57.388  56.882  56.331  55.740  55.111  54.448  53.756
        53.037  52.299  51.544  50.778  50.008  50.778  51.544  52.299  53.037  53.756  54.448  55.111  55.740  56.331  56.882
        57.388  57.847  58.257  58.616  58.923  59.175  59.373  59.514  59.621

  9     59.621  59.514  59.373  59.175  58.923  58.616  58.257  57.847  57.388  56.882  56.331  55.740  55.111  54.448  53.756
        53.037  52.299  51.544  50.778  50.008  50.778  51.544  52.299  53.037  53.756  54.448  55.111  55.740  56.331  56.882
        57.388  57.847  58.257  58.616  58.923  59.175  59.373  59.514  59.621

 10     59.621  59.514  59.373  59.175  58.923  58.616  58.257  57.847  57.388  56.882  56.331  55.740  55.111  54.448  53.756
        53.037  52.299  51.544  50.778  50.008  50.778  51.544  52.299  53.037  53.756  54.448  55.111  55.740  56.331  56.882
        57.388  57.847  58.257  58.616  58.923  59.175  59.373  59.514  59.621

 11     59.621  59.514  59.373  59.175  58.923  58.616  58.257  57.847  57.388  56.882  56.331  55.740  55.111  54.448  53.756
        53.037  52.299  51.544  50.778  50.008  50.778  51.544  52.299  53.037  53.756  54.448  55.111  55.740  56.331  56.882
        57.388  57.847  58.257  58.616  58.923  59.175  59.373  59.514  59.621

 12     59.621  59.514  59.373  59.175  58.923  58.616  58.257  57.847  57.388  56.882  56.331  55.740  55.111  54.448  53.756
        53.037  52.299  51.544  50.778  50.008  50.778  51.544  52.299  53.037  53.756  54.448  55.111  55.740  56.331  56.882
        57.388  57.847  58.257  58.616  58.923  59.175  59.373  59.514  59.621

 13     59.621  59.514  59.373  59.175  58.923  58.616  58.257  57.847  57.388  56.882  56.331  55.740  55.111  54.448  53.756
        53.037  52.299  51.544  50.778  50.008  50.778  51.544  52.299  53.037  53.756  54.448  55.111  55.740  56.331  56.882
        57.388  57.847  58.257  58.616  58.923  59.175  59.373  59.514  59.621
```

VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP 2 IN STRESS PERIOD140

```
        CUMULATIVE VOLUMES      L**3                      RATES FOR THIS TIME STEP      L**3/T
        ------------------                                ------------------------

                IN:                                               IN:
                ---                                               ---
            STORAGE =   0.47028E+09                            STORAGE =    3.7073
      CONSTANT HEAD =   0.00000                          CONSTANT HEAD =    0.00000
           RECHARGE =   0.93224E+09                           RECHARGE =    0.00000
      STREAM LEAKAGE =  0.00000                          STREAM LEAKAGE =   0.00000


           TOTAL IN =   0.14025E+10                           TOTAL IN =    3.7073

                OUT:                                              OUT:
                ----                                              ----
            STORAGE =   0.49468E+09                            STORAGE =    0.00000
      CONSTANT HEAD =   0.00000                          CONSTANT HEAD =    0.00000
           RECHARGE =   0.00000                               RECHARGE =    0.00000
      STREAM LEAKAGE =  0.90735E+09                      STREAM LEAKAGE =   3.7028


          TOTAL OUT =   0.14020E+10                          TOTAL OUT =    3.7028


          IN - OUT =    0.49126E+06                           IN - OUT =    0.45352E-02

   PERCENT DISCREPANCY =                0.04         PERCENT DISCREPANCY =                0.12
```

```
     TIME SUMMARY AT END OF TIME STEP  2 IN STRESS PERIOD140

                         SECONDS         MINUTES         HOURS         DAYS          YEARS
                         -------------------------------------------------------------------
       TIME STEP LENGTH    777600.       12960.0        216.000       9.00000      0.246407E-01
      STRESS PERIOD TIME   0.129600E+07  21600.0        360.000       15.0000      0.410678E-01
   TOTAL SIMULATION TIME   0.181440E+09  0.302400E+07   50400.0       2100.00      5.74949
```

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APPENDIX II

INPUT DATA SETS AND PRINTED RESULTS FOR TEST PROBLEM 2

This problem tests the ability of the Streamflow-Routing Package to calculate stream stage on the basis of flow and to simulate leakage between stream and aquifer. Details of the test problem and results are discussed in the section "Results of Test Simulations."

Listing of Input Data Sets for Test Problem 2

Listing of Input Data for Basic Package

Input for the Basic Package follows the column numbers. The input consists of 40 records (lines). Input for package is read from FORTRAN unit number specified in the MAIN program.

Column Numbers

```
        1         2         3         4         5         6         7         8
12345678901234567890123456789012345678901234567890123456789012345678901234567890
TEST PROBLEM 2--COMPUTATION OF STREAM STAGE FOR A 30-DAY FLOOD: RESULTS COMPARED
TO COOPER AND RORABAUGH (1963)
            1        13        39        32        1
       7                      13      14 15
            0         1
            0         1
          999.
            0      48.0
       86400.        1        1.0
previous line repeated 29 times
     1296000.       15        1.0
     3888000.        9        1.0
```

Listing of Input Data for Strongly-Implicit Procedure Package

Input for the Strongly-Implicit Procedure Package follows the column numbers. The input consists of 2 records (lines). Input for package is read from FORTRAN unit number 13 as specified in the data set for the Basic Package.

Column Numbers

```
        1         2         3         4         5         6         7         8
12345678901234567890123456789012345678901234567890123456789012345678901234567890
      150         5
      1.0   0.0001        1         0         0
```

Listing of Input Data for Block-Centered Flow Package

Input for the Block-Centered Flow Package follows the column numbers. The input consists of 11 records (lines). Input for package is read from FORTRAN unit number 7 as specified in the data set for the Basic Package.

Column Numbers

```
          1         2         3         4         5         6         7         8
12345678901234567890123456789012345678901234567890123456789012345678901234567890
              0         0
0
              0         1.
              7       100.  (15F5.0)
       3.    2.    2.    2.    2.    2.    2.    2.    2.    2.    2.    2.    2.    2.    2.
       2.    2.    2.    2.    2.    2.    2.    2.    2.    2.    2.    2.    2.    2.    2.
       2.    2.    2.    2.    2.    2.    2.    2.    3.
              0      1000.
              0         0.20
              0   0.037000
              0         0.
```

Listing of Input Data for Output Control Package

Input for the Output Control Package follows the column numbers. The input consists of 77 records (lines). Input for package is read from FORTRAN unit number 14 as specified in the data set for the Basic Package.

Column Numbers

```
          1         2         3         4         5         6         7         8
12345678901234567890123456789012345678901234567890123456789012345678901234567890
              5         5         0         0
              0         1         1         1
              1         0         0         0
     previous two lines repeated 29 more times
              0         1         1         1
              1         0         0         0
             -1         1         1         0
     previous line repeated 13 more times
              0         1         1         1
              1         0         0         0
             -1         1         1         0
     previous line repeated 7 more times
```

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Listing of Input Data for Streamflow-Routing Package

Input for the Streamflow-Routing Package follows the column numbers. The input consists of 813 records (lines). Input for package is read from FORTRAN unit number 15 as specified in the data set for the Basic Package.

Column Numbers

```
          1         2         3         4         5         6         7         8
12345678901234567890123456789012345678901234567890123456789012345678901234567890
         13         1         0         0         1     1.486        -1         0
         13         0         0
 1    1   20    1    1          2018.5     48.0    37.000      40.0      40.0
 1    2   20    1    2                     48.0    37.000      40.0      40.0
 1    3   20    1    3                     48.0    37.000      40.0      40.0
 1    4   20    1    4                     48.0    37.000      40.0      40.0
 1    5   20    1    5                     48.0    37.000      40.0      40.0
 1    6   20    1    6                     48.0    37.000      40.0      40.0
 1    7   20    1    7                     48.0    37.000      40.0      40.0
 1    8   20    1    8                     48.0    37.000      40.0      40.0
 1    9   20    1    9                     48.0    37.000      40.0      40.0
 1   10   20    1   10                     48.0    37.000      40.0      40.0
 1   11   20    1   11                     48.0    37.000      40.0      40.0
 1   12   20    1   12                     48.0    37.000      40.0      40.0
 1   13   20    1   13                     48.0    37.000      40.0      40.0
       100.    0.0001  0.02377
       100.    0.0001  0.02377
       100.    0.0001  0.02377
       100.    0.0001  0.02377
       100.    0.0001  0.02377
       100.    0.0001  0.02377
       100.    0.0001  0.02377
       100.    0.0001  0.02377
       100.    0.0001  0.02377
       100.    0.0001  0.02377
       100.    0.0001  0.02377
       100.    0.0001  0.02377
```

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Listing of Input Data for Streamflow-Routing Package (continued)

Sequence of previous 27 lines repeated 29 times except the second line in each sequence changes as listed following the column numbers.

Column Numbers

1		**2**	**3**	**4**	**5**	**6**	**7**	**8**
1234567890	1234567890	1234567890	1234567890	1234567890	1234567890	1234567890	1234567890	
1	1	20	1	1	2073.1	48.0	37.000	40.0	40.0
1	1	20	1	1	2162.2	48.0	37.000	40.0	40.0
1	1	20	1	1	2283.8	48.0	37.000	40.0	40.0
1	1	20	1	1	2434.4	48.0	37.000	40.0	40.0
1	1	20	1	1	2609.0	48.0	37.000	40.0	40.0
1	1	20	1	1	2801.4	48.0	37.000	40.0	40.0
1	1	20	1	1	3003.5	48.0	37.000	40.0	40.0
1	1	20	1	1	3206.7	48.0	37.000	40.0	40.0
1	1	20	1	1	3401.3	48.0	37.000	40.0	40.0
1	1	20	1	1	3577.3	48.0	37.000	40.0	40.0
1	1	20	1	1	3725.7	48.0	37.000	40.0	40.0
1	1	20	1	1	3838.1	48.0	37.000	40.0	40.0
1	1	20	1	1	3908.3	48.0	37.000	40.0	40.0
1	1	20	1	1	3932.1	48.0	37.000	40.0	40.0
1	1	20	1	1	3908.3	48.0	37.000	40.0	40.0
1	1	20	1	1	3838.1	48.0	37.000	40.0	40.0
1	1	20	1	1	3725.7	48.0	37.000	40.0	40.0
1	1	20	1	1	3577.3	48.0	37.000	40.0	40.0
1	1	20	1	1	3401.3	48.0	37.000	40.0	40.0
1	1	20	1	1	3206.7	48.0	37.000	40.0	40.0
1	1	20	1	1	3003.5	48.0	37.000	40.0	40.0
1	1	20	1	1	2801.4	48.0	37.000	40.0	40.0
1	1	20	1	1	2609.0	48.0	37.000	40.0	40.0
1	1	20	1	1	2434.4	48.0	37.000	40.0	40.0
1	1	20	1	1	2283.8	48.0	37.000	40.0	40.0
1	1	20	1	1	2162.2	48.0	37.000	40.0	40.0
1	1	20	1	1	2073.1	48.0	37.000	40.0	40.0
1	1	20	1	1	2018.5	48.0	37.000	40.0	40.0
1	1	20	1	1	2000.0	48.0	37.000	40.0	40.0

last 2 records are as follows:
```
-1
-1
```

SELECTED PAGES FROM PRINTED RESULTS FOR TEST PROBLEM 2

U.S. GEOLOGICAL SURVEY MODULAR FINITE-DIFFERENCE GROUND-WATER MODEL

TEST PROBLEM 2--COMPUTATION OF STREAM STAGE FOR A 30-DAY FLOOD: RESULTS COMPARED TO COOPER AND RORABAUGH (1963)

   1 LAYERS   13 ROWS   39 COLUMNS
  32 STRESS PERIOD(S) IN SIMULATION
MODEL TIME UNIT IS SECONDS

I/O UNITS:
ELEMENT OF IUNIT: 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
        I/O UNIT: 7 0 0 0 0 0 0 0 13 0 0 14 15 0 0 0 0 0 0 0 0 0 0 0

BAS1 -- BASIC MODEL PACKAGE, VERSION 1, 9/1/87 INPUT READ FROM UNIT 5
ARRAYS RHS AND BUFF WILL SHARE MEMORY.
START HEAD WILL BE SAVED
    4619 ELEMENTS IN X ARRAY ARE USED BY BAS
    4619 ELEMENTS OF X ARRAY USED OUT OF 200000

BCF1 -- BLOCK-CENTERED FLOW PACKAGE, VERSION 1, 9/1/87 INPUT READ FROM UNIT 7
TRANSIENT SIMULATION
      LAYER AQUIFER TYPE
      ----
        1   0
     508 ELEMENTS IN X ARRAY ARE USED BY BCF
    5127 ELEMENTS OF X ARRAY USED OUT OF 200000

STRM -- STREAM PACKAGE, VERSION 1, 10/23/87 INPUT READ FROM UNIT 15
MAXIMUM OF   13 STREAM NODES

NUMBER OF STREAM SEGMENTS IS   1

NUMBER OF STREAM TRIBUTARIES IS   0

STREAM STAGES WILL BE CALCULATED USING A CONSTANT OF   1.4860
     210 ELEMENTS IN X ARRAY ARE USED FOR STREAMS
    5337 ELEMENTS OF X ARRAY USED OUT OF 200000

SIP1 -- STRONGLY IMPLICIT PROCEDURE SOLUTION PACKAGE, VERSION 1, 9/1/87 INPUT READ FROM UNIT 13
MAXIMUM OF 150 ITERATIONS ALLOWED FOR CLOSURE
 5 ITERATION PARAMETERS
    2633 ELEMENTS IN X ARRAY ARE USED BY SIP
    7970 ELEMENTS OF X ARRAY USED OUT OF 200000

```
                              STRESS PERIOD NO.  11, LENGTH =    86400.00

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

                              NUMBER OF TIME STEPS =     1

                              MULTIPLIER FOR DELT =     1.000

                              INITIAL TIME STEP SIZE =    86400.00


  13 STREAM NODES

   LAYER   ROW   COL   SEGMENT   REACH   STREAMFLOW    STREAM    STREAMBED    STREAMBED BOT   STREAMBED TOP
                       NUMBER    NUMBER                STAGE     CONDUCTANCE    ELEVATION       ELEVATION
   -------------------------------------------------------------------------------------------------------

      1     1    20      1         1       3577.      48.00       37.00          40.00           40.00
      1     2    20      1         2      0.0000      48.00       37.00          40.00           40.00
      1     3    20      1         3      0.0000      48.00       37.00          40.00           40.00
      1     4    20      1         4      0.0000      48.00       37.00          40.00           40.00
      1     5    20      1         5      0.0000      48.00       37.00          40.00           40.00
      1     6    20      1         6      0.0000      48.00       37.00          40.00           40.00
      1     7    20      1         7      0.0000      48.00       37.00          40.00           40.00
      1     8    20      1         8      0.0000      48.00       37.00          40.00           40.00
      1     9    20      1         9      0.0000      48.00       37.00          40.00           40.00
      1    10    20      1        10      0.0000      48.00       37.00          40.00           40.00
      1    11    20      1        11      0.0000      48.00       37.00          40.00           40.00
      1    12    20      1        12      0.0000      48.00       37.00          40.00           40.00
      1    13    20      1        13      0.0000      48.00       37.00          40.00           40.00


   LAYER   ROW   COL   SEGMENT   REACH     STREAM         STREAM        ROUGH
                       NUMBER    NUMBER    WIDTH          SLOPE         COEF.
   -------------------------------------------------------------------------------------------------------

      1     1    20      1         1       100.0        0.1000E-03     0.2377E-01
      1     2    20      1         2       100.0        0.1000E-03     0.2377E-01
      1     3    20      1         3       100.0        0.1000E-03     0.2377E-01
      1     4    20      1         4       100.0        0.1000E-03     0.2377E-01
      1     5    20      1         5       100.0        0.1000E-03     0.2377E-01
      1     6    20      1         6       100.0        0.1000E-03     0.2377E-01
      1     7    20      1         7       100.0        0.1000E-03     0.2377E-01
      1     8    20      1         8       100.0        0.1000E-03     0.2377E-01
      1     9    20      1         9       100.0        0.1000E-03     0.2377E-01
      1    10    20      1        10       100.0        0.1000E-03     0.2377E-01
      1    11    20      1        11       100.0        0.1000E-03     0.2377E-01
      1    12    20      1        12       100.0        0.1000E-03     0.2377E-01
      1    13    20      1        13       100.0        0.1000E-03     0.2377E-01


    15 ITERATIONS FOR TIME STEP   1 IN STRESS PERIOD 11

 MAXIMUM HEAD CHANGE FOR EACH ITERATION:
```

HEAD CHANGE LAYER,ROW,COL HEAD CHANGE LAYER,ROW,COL HEAD CHANGE LAYER,ROW,COL HEAD CHANGE LAYER,ROW,COL HEAD CHANGE LAYER,ROW,COL

```
 -3.443      ( 1,  1, 20)  3.902      ( 1,  1, 20) -1.044      ( 1, 13, 20)  1.142      ( 1, 13, 20) -0.3119     ( 1, 13, 20)
  0.2921     ( 1, 13, 20) -0.6935E-01 ( 1, 13, 20)  0.5328E-01 ( 1, 13, 20) -0.1243E-01 ( 1, 13, 20)  0.7865E-02 ( 1, 13, 20)
 -0.1882E-02 ( 1, 13, 20)  0.9960E-03 ( 1, 13, 20) -0.2458E-03 ( 1, 13, 20)  0.1229E-03 ( 1, 13, 20) -0.3233E-04 ( 1, 13, 20)
```

HEAD/DRAWDOWN PRINTOUT FLAG = 1   TOTAL BUDGET PRINTOUT FLAG = 1   CELL-BY-CELL FLOW TERM FLAG = 1

OUTPUT FLAGS FOR ALL LAYERS ARE THE SAME:
  HEAD   DRAWDOWN HEAD   DRAWDOWN
PRINTOUT PRINTOUT SAVE   SAVE

```
  1        0        0        0
```

LAYER	ROW	COLUMN	STREAM NUMBER	REACH NUMBER	FLOW INTO STREAM REACH	FLOW INTO AQUIFER	FLOW OUT OF STREAM REACH	HEAD IN STREAM
1	1	20	1	1	0.358E+04	0.721	0.358E+04	51.34
1	2	20	1	2	0.358E+04	0.721	0.358E+04	51.34
1	3	20	1	3	0.358E+04	0.721	0.358E+04	51.33
1	4	20	1	4	0.358E+04	0.721	0.357E+04	51.33
1	5	20	1	5	0.357E+04	0.720	0.357E+04	51.33
1	6	20	1	6	0.357E+04	0.720	0.357E+04	51.33
1	7	20	1	7	0.357E+04	0.720	0.357E+04	51.33
1	8	20	1	8	0.357E+04	0.720	0.357E+04	51.33
1	9	20	1	9	0.357E+04	0.720	0.357E+04	51.33
1	10	20	1	10	0.357E+04	0.720	0.357E+04	51.33
1	11	20	1	11	0.357E+04	0.720	0.357E+04	51.32
1	12	20	1	12	0.357E+04	0.720	0.357E+04	51.32
1	13	20	1	13	0.357E+04	0.719	0.357E+04	51.32

HEAD IN LAYER 1 AT END OF TIME STEP 1 IN STRESS PERIOD 11

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
	31	32	33	34	35	36	37	38	39						

....

1	48.000	48.000	48.000	48.000	48.000	48.000	48.000	48.000	48.000	48.001	48.002	48.006	48.015	48.037	48.088
	48.200	48.437	48.909	49.792	51.318	49.792	48.909	48.437	48.200	48.088	48.037	48.015	48.006	48.002	48.001
	48.000	48.000	48.000	48.000	48.000	48.000	48.000	48.000	48.000						

2	48.000	48.000	48.000	48.000	48.000	48.000	48.000	48.000	48.000	48.001	48.002	48.006	48.015	48.037	48.088
	48.200	48.436	48.908	49.791	51.317	49.791	48.908	48.436	48.200	48.088	48.037	48.015	48.006	48.002	48.001
	48.000	48.000	48.000	48.000	48.000	48.000	48.000	48.000	48.000						

3	48.000	48.000	48.000	48.000	48.000	48.000	48.000	48.000	48.000	48.001	48.002	48.006	48.015	48.037	48.088
	48.200	48.436	48.908	49.790	51.315	49.790	48.908	48.436	48.200	48.088	48.037	48.015	48.006	48.002	48.001
	48.000	48.000	48.000	48.000	48.000	48.000	48.000	48.000	48.000						

4	48.000	48.000	48.000	48.000	48.000	48.000	48.000	48.000	48.000	48.001	48.002	48.006	48.015	48.037	48.088
	48.200	48.436	48.907	49.789	51.314	49.789	48.907	48.436	48.200	48.088	48.037	48.015	48.006	48.002	48.001
	48.000	48.000	48.000	48.000	48.000	48.000	48.000	48.000	48.000						

5	48.000	48.000	48.000	48.000	48.000	48.000	48.000	48.000	48.000	48.001	48.002	48.006	48.015	48.037	48.088
	48.200	48.436	48.907	49.788	51.312	49.788	48.907	48.436	48.200	48.088	48.037	48.015	48.006	48.002	48.001
	48.000	48.000	48.000	48.000	48.000	48.000	48.000	48.000	48.000						

6	48.000	48.000	48.000	48.000	48.000	48.000	48.000	48.000	48.000	48.001	48.002	48.006	48.015	48.037	48.088
	48.200	48.435	48.906	49.788	51.311	49.788	48.906	48.435	48.200	48.088	48.037	48.015	48.006	48.002	48.001
	48.000	48.000	48.000	48.000	48.000	48.000	48.000	48.000	48.000						

7	48.000	48.000	48.000	48.000	48.000	48.000	48.000	48.000	48.000	48.001	48.002	48.006	48.015	48.037	48.088
	48.199	48.435	48.906	49.787	51.310	49.787	48.906	48.435	48.199	48.088	48.037	48.015	48.006	48.002	48.001
	48.000	48.000	48.000	48.000	48.000	48.000	48.000	48.000	48.000						

8	48.000	48.000	48.000	48.000	48.000	48.000	48.000	48.000	48.000	48.001	48.002	48.006	48.015	48.037	48.088
	48.199	48.435	48.905	49.786	51.308	49.786	48.905	48.435	48.199	48.088	48.037	48.015	48.006	48.002	48.001
	48.000	48.000	48.000	48.000	48.000	48.000	48.000	48.000	48.000						

9	48.000	48.000	48.000	48.000	48.000	48.000	48.000	48.000	48.000	48.001	48.002	48.006	48.015	48.037	48.088
	48.199	48.434	48.905	49.785	51.307	49.785	48.905	48.434	48.199	48.088	48.037	48.015	48.006	48.002	48.001
	48.000	48.000	48.000	48.000	48.000	48.000	48.000	48.000	48.000						

10	48.000	48.000	48.000	48.000	48.000	48.000	48.000	48.000	48.000	48.001	48.002	48.006	48.015	48.037	48.088
	48.199	48.434	48.904	49.784	51.306	49.784	48.904	48.434	48.199	48.088	48.037	48.015	48.006	48.002	48.001
	48.000	48.000	48.000	48.000	48.000	48.000	48.000	48.000	48.000						

11	48.000	48.000	48.000	48.000	48.000	48.000	48.000	48.000	48.000	48.001	48.002	48.006	48.015	48.037	48.088
	48.199	48.434	48.904	49.783	51.304	49.783	48.904	48.434	48.199	48.088	48.037	48.015	48.006	48.002	48.001
	48.000	48.000	48.000	48.000	48.000	48.000	48.000	48.000	48.000						

12	48.000	48.000	48.000	48.000	48.000	48.000	48.000	48.000	48.000	48.001	48.002	48.006	48.015	48.037	48.087
	48.199	48.434	48.903	49.782	51.303	49.782	48.903	48.434	48.199	48.087	48.037	48.015	48.006	48.002	48.001
	48.000	48.000	48.000	48.000	48.000	48.000	48.000	48.000	48.000						

13	48.000	48.000	48.000	48.000	48.000	48.000	48.000	48.000	48.000	48.001	48.002	48.006	48.015	48.037	48.087
	48.199	48.433	48.903	49.781	51.301	49.781	48.903	48.433	48.199	48.087	48.037	48.015	48.006	48.002	48.001
	48.000	48.000	48.000	48.000	48.000	48.000	48.000	48.000	48.000						

VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP 1 IN STRESS PERIOD 11

```
          CUMULATIVE VOLUMES      L**3                          RATES FOR THIS TIME STEP      L**3/T
          ------------------                                    ------------------------

                    IN:                                                   IN:
                    ---                                                   ---
               STORAGE =   0.00000                                   STORAGE =   0.00000
         CONSTANT HEAD =   0.00000                             CONSTANT HEAD =   0.00000
        STREAM LEAKAGE =   0.53424E+07                        STREAM LEAKAGE =   9.3624


              TOTAL IN =   0.53424E+07                              TOTAL IN =   9.3624

                   OUT:                                                  OUT:
                   ----                                                  ----
               STORAGE =   0.53371E+07                               STORAGE =   9.3589
         CONSTANT HEAD =   0.00000                             CONSTANT HEAD =   0.00000
        STREAM LEAKAGE =   0.00000                            STREAM LEAKAGE =   0.00000


             TOTAL OUT =   0.53371E+07                             TOTAL OUT =   9.3589

             IN - OUT =    5253.0                                  IN - OUT =   0.34771E-02


      PERCENT DISCREPANCY =            0.10                  PERCENT DISCREPANCY =              0.04
```


```
        TIME SUMMARY AT END OF TIME STEP  1 IN STRESS PERIOD 11

                           SECONDS      MINUTES       HOURS        DAYS        YEARS
                          -------------------------------------------------------------------
        TIME STEP LENGTH     86400.0     1440.00     24.0000     1.00000     0.273785E-02
       STRESS PERIOD TIME    86400.0     1440.00     24.0000     1.00000     0.273785E-02
     TOTAL SIMULATION TIME   950400.     15840.0     264.000     11.0000     0.301164E-01
```

NUMBER OF TIME STEPS =   1

MULTIPLIER FOR DELT =   1.000

INITIAL TIME STEP SIZE =   86400.00

13 STREAM NODES

.

LAYER	ROW	COL	SEGMENT NUMBER	REACH NUMBER	STREAMFLOW	STREAM STAGE	STREAMBED CONDUCTANCE	STREAMBED BOT ELEVATION	STREAMBED TOP ELEVATION
1	1	20	1	1	2018.	48.00	37.00	40.00	40.00
1	2	20	1	2	0.0000	48.00	37.00	40.00	40.00
1	3	20	1	3	0.0000	48.00	37.00	40.00	40.00
1	4	20	1	4	0.0000	48.00	37.00	40.00	40.00
1	5	20	1	5	0.0000	48.00	37.00	40.00	40.00
1	6	20	1	6	0.0000	48.00	37.00	40.00	40.00
1	7	20	1	7	0.0000	48.00	37.00	40.00	40.00
1	8	20	1	8	0.0000	48.00	37.00	40.00	40.00
1	9	20	1	9	0.0000	48.00	37.00	40.00	40.00
1	10	20	1	10	0.0000	48.00	37.00	40.00	40.00
1	11	20	1	11	0.0000	48.00	37.00	40.00	40.00
1	12	20	1	12	0.0000	48.00	37.00	40.00	40.00
1	13	20	1	13	0.0000	48.00	37.00	40.00	40.00

LAYER	ROW	COL	SEGMENT NUMBER	REACH NUMBER	STREAM WIDTH	STREAM SLOPE	ROUGH COEF.
1	1	20	1	1	100.0	0.1000E-03	0.2377E-01
1	2	20	1	2	100.0	0.1000E-03	0.2377E-01
1	3	20	1	3	100.0	0.1000E-03	0.2377E-01
1	4	20	1	4	100.0	0.1000E-03	0.2377E-01
1	5	20	1	5	100.0	0.1000E-03	0.2377E-01
1	6	20	1	6	100.0	0.1000E-03	0.2377E-01
1	7	20	1	7	100.0	0.1000E-03	0.2377E-01
1	8	20	1	8	100.0	0.1000E-03	0.2377E-01
1	9	20	1	9	100.0	0.1000E-03	0.2377E-01
1	10	20	1	10	100.0	0.1000E-03	0.2377E-01
1	11	20	1	11	100.0	0.1000E-03	0.2377E-01
1	12	20	1	12	100.0	0.1000E-03	0.2377E-01
1	13	20	1	13	100.0	0.1000E-03	0.2377E-01

15 ITERATIONS FOR TIME STEP   1 IN STRESS PERIOD 29

MAXIMUM HEAD CHANGE FOR EACH ITERATION:

HEAD CHANGE LAYER,ROW,COL HEAD CHANGE LAYER,ROW,COL HEAD CHANGE LAYER,ROW,COL HEAD CHANGE LAYER,ROW,COL HEAD CHANGE LAYER,ROW,COL

   -2.814   (1, 1, 20)   2.807   (1, 1, 20) -0.9299   (1, 13, 20)   0.9100   (1, 13, 20) -0.3413   (1, 13, 20)
   0.2986   (1, 13, 20) -0.9357E-01 (1, 13, 20) 0.6964E-01 (1, 13, 20) -0.2084E-01 (1, 13, 20) 0.1315E-01 (1, 13, 20)
  -0.3939E-02 (1, 13, 20) 0.2134E-02 (1, 13, 20) -0.6467E-03 (1, 13, 20) 0.3104E-03 (1, 13, 20) -0.9701E-04 (1, 13, 20)

HEAD/DRAWDOWN PRINTOUT FLAG = 1   TOTAL BUDGET PRINTOUT FLAG = 1   CELL-BY-CELL FLOW TERM FLAG = 1

OUTPUT FLAGS FOR ALL LAYERS ARE THE SAME:
  HEAD   DRAWDOWN HEAD DRAWDOWN
PRINTOUT PRINTOUT SAVE   SAVE
----
   1   0   0   0

LAYER	ROW	COLUMN	STREAM NUMBER	REACH NUMBER	FLOW INTO STREAM REACH	FLOW INTO AQUIFER	FLOW OUT OF STREAM REACH	HEAD IN STREAM
1	1	20	1	1	0.202E+04	-.329	0.202E+04	48.04
1	2	20	1	2	0.202E+04	-.329	0.202E+04	48.04
1	3	20	1	3	0.202E+04	-.329	0.202E+04	48.05
1	4	20	1	4	0.202E+04	-.329	0.202E+04	48.05
1	5	20	1	5	0.202E+04	-.329	0.202E+04	48.05
1	6	20	1	6	0.202E+04	-.329	0.202E+04	48.05
1	7	20	1	7	0.202E+04	-.329	0.202E+04	48.05
1	8	20	1	8	0.202E+04	-.329	0.202E+04	48.05
1	9	20	1	9	0.202E+04	-.329	0.202E+04	48.05
1	10	20	1	10	0.202E+04	-.329	0.202E+04	48.05
1	11	20	1	11	0.202E+04	-.328	0.202E+04	48.05
1	12	20	1	12	0.202E+04	-.328	0.202E+04	48.05
1	13	20	1	13	0.202E+04	-.327	0.202E+04	48.05

HEAD IN LAYER 1 AT END OF TIME STEP 1 IN STRESS PERIOD 29

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
	31	32	33	34	35	36	37	38	39						

....

```
 1   48.000  48.000  48.001  48.002  48.004  48.007  48.013  48.025  48.045  48.078  48.133  48.218  48.342  48.510  48.717
     48.934  49.095  49.091  48.779  48.052  48.779  49.091  49.095  48.934  48.717  48.510  48.342  48.218  48.133  48.078
     48.045  48.025  48.013  48.007  48.004  48.002  48.001  48.000  48.000


 2   48.000  48.000  48.001  48.002  48.004  48.007  48.013  48.025  48.045  48.078  48.133  48.218  48.342  48.510  48.717
     48.934  49.095  49.091  48.780  48.053  48.780  49.091  49.095  48.934  48.717  48.510  48.342  48.218  48.133  48.078
     48.045  48.025  48.013  48.007  48.004  48.002  48.001  48.000  48.000


 3   48.000  48.000  48.001  48.002  48.004  48.007  48.013  48.025  48.045  48.078  48.133  48.218  48.342  48.510  48.717
     48.934  49.095  49.091  48.780  48.054  48.780  49.091  49.095  48.934  48.717  48.510  48.342  48.218  48.133  48.078
     48.045  48.025  48.013  48.007  48.004  48.002  48.001  48.000  48.000


 4   48.000  48.000  48.001  48.002  48.004  48.007  48.013  48.025  48.045  48.078  48.133  48.218  48.341  48.510  48.717
     48.933  49.095  49.091  48.781  48.055  48.781  49.091  49.095  48.933  48.717  48.510  48.341  48.218  48.133  48.078
     48.045  48.025  48.013  48.007  48.004  48.002  48.001  48.000  48.000


 5   48.000  48.000  48.001  48.002  48.004  48.007  48.013  48.025  48.045  48.078  48.133  48.218  48.341  48.510  48.716
     48.933  49.095  49.091  48.781  48.056  48.781  49.091  49.095  48.933  48.716  48.510  48.341  48.218  48.133  48.078
     48.045  48.025  48.013  48.007  48.004  48.002  48.001  48.000  48.000


 6   48.000  48.000  48.001  48.002  48.004  48.007  48.013  48.025  48.045  48.078  48.133  48.218  48.341  48.509  48.716
     48.933  49.095  49.092  48.782  48.056  48.782  49.092  49.095  48.933  48.716  48.509  48.341  48.218  48.133  48.078
     48.045  48.025  48.013  48.007  48.004  48.002  48.001  48.000  48.000


 7   48.000  48.000  48.001  48.002  48.004  48.007  48.013  48.025  48.045  48.078  48.133  48.217  48.341  48.509  48.716
     48.933  49.095  49.092  48.782  48.057  48.782  49.092  49.095  48.933  48.716  48.509  48.341  48.217  48.133  48.078
     48.045  48.025  48.013  48.007  48.004  48.002  48.001  48.000  48.000


 8   48.000  48.000  48.001  48.002  48.004  48.007  48.013  48.025  48.045  48.078  48.133  48.217  48.341  48.509  48.716
     48.933  49.095  49.092  48.782  48.058  48.782  49.092  49.095  48.933  48.716  48.509  48.341  48.217  48.133  48.078
     48.045  48.025  48.013  48.007  48.004  48.002  48.001  48.000  48.000


 9   48.000  48.000  48.001  48.002  48.004  48.007  48.013  48.025  48.044  48.078  48.133  48.217  48.341  48.509  48.716
     48.933  49.095  49.092  48.783  48.059  48.783  49.092  49.095  48.933  48.716  48.509  48.341  48.217  48.133  48.078
     48.044  48.025  48.013  48.007  48.004  48.002  48.001  48.000  48.000


10   48.000  48.000  48.001  48.002  48.004  48.007  48.013  48.025  48.044  48.078  48.133  48.217  48.341  48.509  48.716
     48.933  49.095  49.092  48.783  48.059  48.783  49.092  49.095  48.933  48.716  48.509  48.341  48.217  48.133  48.078
     48.044  48.025  48.013  48.007  48.004  48.002  48.001  48.000  48.000


11   48.000  48.000  48.001  48.002  48.004  48.007  48.013  48.025  48.044  48.078  48.133  48.217  48.341  48.509  48.716
     48.932  49.095  49.092  48.784  48.060  48.784  49.092  49.095  48.932  48.716  48.509  48.341  48.217  48.133  48.078
     48.044  48.025  48.013  48.007  48.004  48.002  48.001  48.000  48.000


12   48.000  48.000  48.001  48.002  48.004  48.007  48.013  48.025  48.044  48.078  48.133  48.217  48.341  48.509  48.715
     48.932  49.095  49.093  48.784  48.061  48.784  49.093  49.095  48.932  48.715  48.509  48.341  48.217  48.133  48.078
     48.044  48.025  48.013  48.007  48.004  48.002  48.001  48.000  48.000


13   48.000  48.000  48.001  48.002  48.004  48.007  48.013  48.025  48.044  48.078  48.133  48.217  48.341  48.509  48.715
     48.932  49.095  49.093  48.785  48.062  48.785  49.093  49.095  48.932  48.715  48.509  48.341  48.217  48.133  48.078
     48.044  48.025  48.013  48.007  48.004  48.002  48.001  48.000  48.000
```

VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP 1 IN STRESS PERIOD 29

```
      CUMULATIVE VOLUMES      L**3                        RATES FOR THIS TIME STEP      L**3/T
      ------------------                                  ------------------------


            IN:                                                 IN:
            ---                                                 ---
              STORAGE =   0.52264E+07                             STORAGE =    5.3231
        CONSTANT HEAD =   0.00000                           CONSTANT HEAD =    0.00000
       STREAM LEAKAGE =   0.94751E+07                       STREAM LEAKAGE =   0.00000


             TOTAL IN =   0.14701E+08                            TOTAL IN =    5.3231

            OUT:                                                OUT:
            ----                                                ----
              STORAGE =   0.11489E+08                             STORAGE =    1.0429
        CONSTANT HEAD =   0.00000                           CONSTANT HEAD =    0.00000
       STREAM LEAKAGE =   0.32005E+07                       STREAM LEAKAGE =   4.2724


            TOTAL OUT =   0.14689E+08                           TOTAL OUT =    5.3153


            IN - OUT =    12434.                               IN - OUT =   0.77477E-02



      PERCENT DISCREPANCY =              0.08               PERCENT DISCREPANCY =              0.15
```


TIME SUMMARY AT END OF TIME STEP 1 IN STRESS PERIOD 29

	SECONDS	MINUTES	HOURS	DAYS	YEARS
TIME STEP LENGTH	86400.0	1440.00	24.0000	1.00000	0.273785E-02
STRESS PERIOD TIME	86400.0	1440.00	24.0000	1.00000	0.273785E-02
TOTAL SIMULATION TIME	0.250560E+07	41760.0	696.000	29.0000	0.793977E-01

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APPENDIX III

INPUT DATA SETS AND PRINTED RESULTS FOR EXAMPLE PROBLEM

This problem is an example of the capabilities of the Streamflow-Routing Package. Details of the test problem and results are discussed in the section "Results of Test Simulations."

Listing of Input Data Sets for Example Problem

Listing of Input Data for Basic Package

Input for the Basic Package follows the column numbers. The input consists of 15 records (lines). Input for package is read from a FORTRAN unit number specified in the MAIN program.

Column Numbers

```
        1         2         3         4         5         6         7         8
12345678901234567890123456789012345678901234567890123456789012345678901234567890
EXAMPLE SIMULATION OF STREAM ROUTING PACKAGE -- STEADY STATE   OCTOBER  21,1987
-- STREAM STAGE IS CALCULATED
          1         6         6         1         1
    7                    13        14 15
          0         1
          0         1
      999.
          5         1.0 (6F8.0)
   480.00   480.00   480.00   480.00   480.00   480.00
   480.00   480.00   480.00   480.00   480.00   480.00
   480.00   480.00   480.00   480.00   480.00   480.00
   480.00   480.00   480.00   480.00   480.00   480.00
   480.00   480.00   480.00   480.00   480.00   480.00
   480.00   480.00   480.00   480.00   480.00   480.00
 1296000.         3         1.5
```

Listing of Input Data for Strongly-Implicit Procedure Package

Input for the Strongly-Implicit Procedure Package follows the column numbers. The input consists of 2 records (lines). Input for package is read from FORTRAN unit number 13 as specified in the data set for the Basic Package.

Listing of Input Data for Strongly-Implicit Procedure Package (continued)

Column Numbers

```
         1         2         3         4         5         6         7         8
12345678901234567890123456789012345678901234567890123456789012345678901234567890
       150         5
         1.   0.0001         1         0         0
```

Listing of Input Data for Block-Centered Flow Package

Input for the Block-Centered Flow Package follows the column numbers.
The input consists of 7 records (lines). Input for package is read from FORTRAN
unit number 7 as specified in the data set for the Basic Package.

Column Numbers

```
         1         2         3         4         5         6         7         8
12345678901234567890123456789012345678901234567890123456789012345678901234567890
           1         0
 0
           0         1.
           0      1000.
           0      1000.
           0  0.080000
           0         0.
```

Listing of Input Data for Output Control Package

Input for the Output Control Package follows the column numbers. The input
consists of 7 records (lines). Input for package is read from FORTRAN unit
number 14 as specified in the data set for the Basic Package.

Column Numbers

```
         1         2         3         4         5         6         7         8
12345678901234567890123456789012345678901234567890123456789012345678901234567890
         5         5         0         0
         0         0         0         0
         0         0         0         0
         0         0         0         0
         0         0         0         0
         0         1         1         1
         1         0         0         0
```

Input for the Streamflow-Routing Package follows the column numbers. The input consists of 62 records (lines). Input for package is read from FORTRAN unit number 15 as specified in the data set for the Basic Package.

Column Numbers

```
         1         2         3         4         5         6         7         8
12345678901234567890123456789012345678901234567890123456789012345678901234567890
      23        7         3         1         1    1.486        -1         0
      23        0         0
 1    1    3    1    1    4.5   495.0     1.20     490.0     492.0
 1    2    3    1    2          490.0     0.60     485.0     487.0
 1    2    3    2    1    1.5   487.0     0.20     483.0     485.0
 1    3    3    2    2          486.0     0.40     482.0     484.0
 1    4    3    2    3          484.0     0.40     480.0     482.0
 1    5    3    2    4          480.0     0.20     476.0     478.0
 1    2    3    3    1   -1.0   486.0     0.40     481.0     483.0
 1    3    4    3    2          482.0     1.20     477.0     479.0
 1    4    4    3    3          478.0     1.20     473.0     475.0
 1    5    4    3    4          475.0     0.60     470.0     472.0
 1    4    1    4    1    0.8   492.0     0.40     489.0     490.0
 1    4    2    4    2          488.0     0.32     485.0     486.0
 1    5    2    4    3          483.0     0.32     480.0     481.0
 1    5    3    4    4          480.0     0.20     477.0     478.0
 1    5    3    5    1   -1.0   478.0     0.20     475.0     476.0
 1    5    4    5    2          474.0     0.20     471.0     472.0
 1    2    6    6    1    1.2   495.0     0.80     491.0     493.0
 1    3    6    6    2          490.0     0.80     486.0     488.0
 1    4    5    6    3          480.0     0.80     476.0     478.0
 1    5    5    6    4          477.0     0.60     473.0     475.0
 1    5    4    6    5          474.0     0.20     470.0     472.0
 1    5    4    7    1   -1.0   472.0     0.60     467.0     469.0
 1    6    4    7    2          469.0     1.20     464.0     466.0
      10.      0.007     0.030
      10.      0.007     0.030
       5.      0.002     0.022
       5.      0.002     0.022
       5.      0.002     0.022
       5.      0.004     0.022
      10.      0.005     0.030
      10.      0.005     0.030
      10.      0.005     0.030
      10.      0.005     0.030
       5.      0.004     0.022
       5.      0.004     0.022
       5.      0.004     0.022
       5.      0.004     0.022
       5.      0.005     0.022
       5.      0.005     0.022
```

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Column Numbers

```
         1         2         3         4         5         6         7         8
12345678901234567890123456789012345678901234567890123456789012345678901234567890
         5.      0.005     0.022
         5.      0.008     0.022
         5.      0.007     0.022
         5.      0.004     0.022
         5.      0.003     0.022
        10.      0.004     0.030
        10.      0.004     0.030
    0    0    0
    0    0    0
    1    0    0
    0    0    0
    2    4    0
    0    0    0
    3    5    6
         0
         1
         0
         0
         0
         0
         0
```

PRINTED RESULTS FOR EXAMPLE PROBLEM

U.S. GEOLOGICAL SURVEY MODULAR FINITE-DIFFERENCE GROUND-WATER MODEL

EXAMPLE SIMULATION OF STREAM ROUTING PACKAGE -- STEADY STATE OCTOBER 21, 1987 -- STREAM STAGE IS CALCULATED

   1 LAYERS   6 ROWS   6 COLUMNS

   1 STRESS PERIOD(S) IN SIMULATION

MODEL TIME UNIT IS SECONDS

I/O UNITS:

ELEMENT OF IUNIT: 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
         I/O UNIT: 7 0 0 0 0 0 0 0 13 0 0 14 15 0 0 0 0 0 0 0 0 0 0 0

BAS1 -- BASIC MODEL PACKAGE, VERSION 1, 9/1/87 INPUT READ FROM UNIT 5
ARRAYS RHS AND BUFF WILL SHARE MEMORY.
START HEAD WILL BE SAVED
     340 ELEMENTS IN X ARRAY ARE USED BY BAS
     340 ELEMENTS OF X ARRAY USED OUT OF 200000

BCF1 -- BLOCK-CENTERED FLOW PACKAGE, VERSION 1, 9/1/87 INPUT READ FROM UNIT 7
STEADY-STATE SIMULATION
     LAYER AQUIFER TYPE
     ----
        1   0

       1 ELEMENTS IN X ARRAY ARE USED BY BCF
     341 ELEMENTS OF X ARRAY USED OUT OF 200000

STRM -- STREAM PACKAGE, VERSION 1, 10/23/87 INPUT READ FROM UNIT 15
MAXIMUM OF   23 STREAM NODES

NUMBER OF STREAM SEGMENTS IS   7

NUMBER OF STREAM TRIBUTARIES IS   3

DIVERSIONS FROM STREAMS HAVE BEEN SPECIFIED
STREAM STAGES WILL BE CALCULATED USING A CONSTANT OF   1.4860

     403 ELEMENTS IN X ARRAY ARE USED FOR STREAMS
     744 ELEMENTS OF X ARRAY USED OUT OF 200000

SIP1 -- STRONGLY IMPLICIT PROCEDURE SOLUTION PACKAGE, VERSION 1, 9/1/87 INPUT READ FROM UNIT 13
MAXIMUM OF 150 ITERATIONS ALLOWED FOR CLOSURE

   5 ITERATION PARAMETERS

     749 ELEMENTS IN X ARRAY ARE USED BY SIP
    1493 ELEMENTS OF X ARRAY USED OUT OF 200000

EXAMPLE SIMULATION OF STREAM ROUTING PACKAGE -- STEADY STATE OCTOBER 21, 1987   -- STREAM STAGE IS CALCULATED

BOUNDARY ARRAY =   1 FOR LAYER 1

AQUIFER HEAD WILL BE SET TO 999.00   AT ALL NO-FLOW NODES (IBOUND=0).

INITIAL HEAD FOR LAYER 1 WILL BE READ ON UNIT 5 USING FORMAT: (6F8.0)

	1	2	3	4	5	6
1	480.0	480.0	480.0	480.0	480.0	480.0
2	480.0	480.0	480.0	480.0	480.0	480.0
3	480.0	480.0	480.0	480.0	480.0	480.0
4	480.0	480.0	480.0	480.0	480.0	480.0
5	480.0	480.0	480.0	480.0	480.0	480.0
6	480.0	480.0	480.0	480.0	480.0	480.0

HEAD PRINT FORMAT IS FORMAT NUMBER   5   DRAWDOWN PRINT FORMAT IS FORMAT NUMBER   5

HEADS WILL BE SAVED ON UNIT 0   DRAWDOWNS WILL BE SAVED ON UNIT 0

OUTPUT CONTROL IS SPECIFIED EVERY TIME STEP

COLUMN TO ROW ANISOTROPY = 1.000000

DELR = 1000.000

DELC = 1000.000

TRANSMIS. ALONG ROWS = 0.8000000E-01 FOR LAYER 1

SOLUTION BY THE STRONGLY IMPLICIT PROCEDURE

MAXIMUM ITERATIONS ALLOWED FOR CLOSURE =   150
ACCELERATION PARAMETER =   1.0000
HEAD CHANGE CRITERION FOR CLOSURE =   0.10000E-03
SIP HEAD CHANGE PRINTOUT INTERVAL =   999
CALCULATE ITERATION PARAMETERS FROM MODEL CALCULATED WSEED

STRESS PERIOD NO.   1, LENGTH =   1296000.

NUMBER OF TIME STEPS =   3

MULTIPLIER FOR DELT =   1.500

INITIAL TIME STEP SIZE =   272842.1

23 STREAM NODES

LAYER	ROW	COL	SEGMENT NUMBER	REACH NUMBER	STREAMFLOW	STREAM STAGE	STREAMBED CONDUCTANCE	STREAMBED BOT ELEVATION	STREAMBED TOP ELEVATION
1	1	3	1	1	4.500	495.0	1.200	490.0	492.0
1	2	3	1	2	0.0000	490.0	0.6000	485.0	487.0
1	2	3	2	1	1.500	487.0	0.2000	483.0	485.0
1	3	3	2	2	0.0000	486.0	0.4000	482.0	484.0
1	4	3	2	3	0.0000	484.0	0.4000	480.0	482.0
1	5	3	2	4	0.0000	480.0	0.2000	476.0	478.0
1	2	3	3	1	-1.000	486.0	0.4000	481.0	483.0
1	3	4	3	2	0.0000	482.0	1.200	477.0	479.0
1	4	4	3	3	0.0000	478.0	1.200	473.0	475.0
1	5	4	3	4	0.0000	475.0	0.6000	470.0	472.0
1	4	1	4	1	0.8000	492.0	0.4000	489.0	490.0
1	4	2	4	2	0.0000	488.0	0.3200	485.0	486.0
1	5	2	4	3	0.0000	483.0	0.3200	480.0	481.0
1	5	3	4	4	0.0000	480.0	0.2000	477.0	478.0
1	5	3	5	1	-1.000	478.0	0.2000	475.0	476.0
1	5	4	5	2	0.0000	474.0	0.2000	471.0	472.0
1	2	6	6	1	1.200	495.0	0.8000	491.0	493.0
1	3	6	6	2	0.0000	490.0	0.8000	486.0	488.0
1	4	5	6	3	0.0000	480.0	0.8000	476.0	478.0
1	5	5	6	4	0.0000	477.0	0.6000	473.0	475.0
1	5	4	6	5	0.0000	474.0	0.2000	470.0	472.0
1	5	4	7	1	-1.000	472.0	0.6000	467.0	469.0
1	6	4	7	2	0.0000	469.0	1.200	464.0	466.0

LAYER	ROW	COL	SEGMENT NUMBER	REACH NUMBER	STREAM WIDTH	STREAM SLOPE	ROUGH COEF
1	1	3	1	1	10.00	0.7000E-02	0.3000E-01
1	2	3	1	2	10.00	0.7000E-02	0.3000E-01
1	2	3	2	1	5.000	0.2000E-02	0.2200E-01
1	3	3	2	2	5.000	0.2000E-02	0.2200E-01
1	4	3	2	3	5.000	0.2000E-02	0.2200E-01
1	5	3	2	4	5.000	0.4000E-02	0.2200E-01
1	2	3	3	1	10.00	0.5000E-02	0.3000E-01
1	3	4	3	2	10.00	0.5000E-02	0.3000E-01
1	4	4	3	3	10.00	0.5000E-02	0.3000E-01
1	5	4	3	4	10.00	0.5000E-02	0.3000E-01
1	4	1	4	1	5.000	0.4000E-02	0.2200E-01
1	4	2	4	2	5.000	0.4000E-02	0.2200E-01
1	5	2	4	3	5.000	0.4000E-02	0.2200E-01
1	5	3	4	4	5.000	0.4000E-02	0.2200E-01
1	5	3	5	1	5.000	0.5000E-02	0.2200E-01
1	5	4	5	2	5.000	0.5000E-02	0.2200E-01
1	2	6	6	1	5.000	0.5000E-02	0.2200E-01
1	3	6	6	2	5.000	0.8000E-02	0.2200E-01
1	4	5	6	3	5.000	0.7000E-02	0.2200E-01
1	5	5	6	4	5.000	0.4000E-02	0.2200E-01
1	5	4	6	5	5.000	0.3000E-02	0.2200E-01
1	5	4	7	1	10.00	0.4000E-02	0.3000E-01
1	6	4	7	2	10.00	0.4000E-02	0.3000E-01

MAXIMUM NUMBER OF TRIBUTARY STREAMS IS   3

STREAM SEGMENT	TRIBUTARY STREAM SEGMENT NUMBERS		
1	0	0	0
2	0	0	0
3	1	0	0
4	0	0	0
5	2	4	0
6	0	0	0
7	3	5	6

DIVERSION SEGMENT NUMBER	UPSTREAM SEGMENT NUMBER
1	0
2	1
3	0
4	0
5	0
6	0
7	0

AVERAGE SEED = 0.06853890

MINIMUM SEED = 0.06853890

    5 ITERATION PARAMETERS CALCULATED FROM AVERAGE SEED:

        0.0000000E+00 0.4883367E+00 0.7382007E+00 0.8660468E+00 0.9314611E+00

    20 ITERATIONS FOR TIME STEP   1 IN STRESS PERIOD 1

HEAD/DRAWDOWN PRINTOUT FLAG = 0   TOTAL BUDGET PRINTOUT FLAG = 0   CELL-BY-CELL FLOW TERM FLAG = 0

OUTPUT FLAGS FOR ALL LAYERS ARE THE SAME:

   HEAD   DRAWDOWN HEAD   DRAWDOWN
PRINTOUT PRINTOUT SAVE   SAVE
----
    0   0   0   0

    1 ITERATIONS FOR TIME STEP   2 IN STRESS PERIOD 1

HEAD/DRAWDOWN PRINTOUT FLAG = 0   TOTAL BUDGET PRINTOUT FLAG = 0   CELL-BY-CELL FLOW TERM FLAG = 0

OUTPUT FLAGS FOR ALL LAYERS ARE THE SAME:

   HEAD   DRAWDOWN HEAD   DRAWDOWN
PRINTOUT PRINTOUT SAVE   SAVE
----
    0   0   0   0

    1 ITERATIONS FOR TIME STEP   3 IN STRESS PERIOD 1

MAXIMUM HEAD CHANGE FOR EACH ITERATION:

  HEAD CHANGE LAYER,ROW,COL HEAD CHANGE LAYER,ROW,COL HEAD CHANGE LAYER,ROW,COL HEAD CHANGE LAYER,ROW,COL HEAD CHANGE AYER,ROW,COL

  0.2274E-06 (1, 5, 4)

HEAD/DRAWDOWN PRINTOUT FLAG = 1   TOTAL BUDGET PRINTOUT FLAG = 1   CELL-BY-CELL FLOW TERM FLAG = 1

OUTPUT FLAGS FOR ALL LAYERS ARE THE SAME:

   HEAD   DRAWDOWN HEAD   DRAWDOWN
PRINTOUT PRINTOUT SAVE   SAVE
----
    1   0   0   0

LAYER	ROW	COLUMN	STREAM NUMBER	REACH NUMBER	FLOW INTO STREAM REACH	FLOW INTO AQUIFER	FLOW OUT OF STREAM REACH	HEAD IN STREAM
1	1	3	1	1	4.50	0.931	3.57	492.25
1	2	3	1	2	3.57	0.841	1.23	487.18
1	2	3	2	1	1.50	-.105	1.60	485.26
1	3	3	2	2	1.60	0.222	1.38	484.25
1	4	3	2	3	1.38	0.357	1.03	482.22
1	5	3	2	4	1.03	0.221	0.805	478.15
1	2	3	3	1	1.23	-1.05	2.27	483.17
1	3	4	3	2	2.27	-.663	2.94	479.21
1	4	4	3	3	2.94	-.612	3.55	475.24
1	5	4	3	4	3.55	0.455	3.09	472.24
1	4	1	4	1	0.800	0.446	0.354	490.11
1	4	2	4	2	0.354	0.339	0.157E-01	486.06
1	5	2	4	3	0.157E-01	0.157E-01	0.000	481.01
1	5	3	4	4	0.000	0.000	0.000	478.00
1	5	3	5	1	0.805	-.182	0.987	476.14
1	5	4	5	2	0.987	0.131	0.855	472.14
1	2	6	6	1	1.20	1.01	0.187	493.12
1	3	6	6	2	0.187	0.187	0.000	488.03
1	4	5	6	3	0.000	-.587E-01	0.587E-01	478.02
1	5	5	6	4	0.587E-01	0.587E-01	0.000	475.02
1	5	4	6	5	0.000	0.000	0.000	472.00
1	5	4	7	1	3.95	-1.30	5.25	469.32
1	6	4	7	2	5.25	-1.25	6.50	466.37

HEAD IN LAYER 1 AT END OF TIME STEP 3 IN STRESS PERIOD 1

	1	2	3	4	5	6
1	487.639	488.554	491.471	488.439	488.579	490.216
2	486.725	486.551	485.779	485.266	487.082	491.854
3	485.985	485.144	483.696	479.763	482.630	485.603
4	486.087	484.345	481.326	475.750	478.073	479.984
5	482.357	480.593	477.047	471.485	474.663	476.275
6	480.392	478.426	474.294	467.409	472.084	474.179

VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP 3 IN STRESS PERIOD 1

CUMULATIVE VOLUMES L**3	RATES FOR THIS TIME STEP L**3/T

IN:

STORAGE = 0.00000	STORAGE = 0.00000
CONSTANT HEAD = 0.00000	CONSTANT HEAD = 0.00000
STREAM LEAKAGE = 0.67615E+07	STREAM LEAKAGE = 5.2172
TOTAL IN = 0.67615E+07	TOTAL IN = 5.2172

OUT:

STORAGE = 0.00000	STORAGE = 0.00000
CONSTANT HEAD = 0.00000	CONSTANT HEAD = 0.00000
STREAM LEAKAGE = 0.67619E+07	STREAM LEAKAGE = 5.2175
TOTAL OUT = 0.67619E+07	TOTAL OUT = 5.2175
IN - OUT = -352.00	IN - OUT = -0.29469E-03
PERCENT DISCREPANCY = -0.01	PERCENT DISCREPANCY = -0.01

TIME SUMMARY AT END OF TIME STEP 3 IN STRESS PERIOD 1

	SECONDS	MINUTES	HOURS	DAYS	YEARS
TIME STEP LENGTH	613894.	10231.6	170.526	7.10526	0.194531E-01
STRESS PERIOD TIME	0.129600E+07	21600.0	360.000	15.0000	0.410677E-01
TOTAL SIMULATION TIME	0.129600E+07	21600.0	360.000	15.0000	0.410677E-01

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